REPORT
1966

NORTHEASTERN FOREST
EXPERIMENT STATION

FOREST SERVICE • U. S. DEPARTMENT OF AGRICULTURE • UPPER DARBY, PA.

REPORT 1966

Northeastern Forest Experiment Station

Contents

State of the Station 1
Timber management 3
Watershed management 14
Forest economics 21
Forest survey 24
Forest recreation 26
Wildlife habitat 28
Forest insects & diseases 31
Forest products marketing 51
Utilization research 60
Forest engineering 66
Publications 71

NORTHEASTERN FOREST EXPERIMENT STATION 1967
Richard D. Lane, Director

STATE OF THE STATION

THE STATE of the Station is good! Our former Director, Ralph Marquis, left the Northeastern Station in an excellent condition when he transferred to the Chief's Office in Washington early in 1966, and the Station is continuing to move ahead dynamically.

Typical of our time, 1966 has been a year of change for us — changes accompanied by new problems for research, new opportunities for improvement in management and organization, and new challenges to both our research scientists and administrators. It was darkened by the deaths of Ralph Marquis, Frank Longwood, and George Cashion. Also we lost some of our top hands through retirement—E. Garth Champagne and Russell R. Whitten—as well as through transfers to other Forest Service and government offices and resignations to accept positions elsewhere.

We made good advancements on some fronts, lost ground on some, and held our own on others. All in all, we made substantial progress on our primary mission: to contribute new knowledge that will advance the science and practice of forestry in the Northeast.

The major part of this report is devoted to highlighting some of our research activities and accomplishments in 1966. However, there were some other important developments, and the more significant ones are described below.

Reorganization

The reorganization of the Station, part of the Forest Service's reorganization of its programs in the East, was practically completed in 1966. This reorganization increased the area we serve, our staff, the number of our projects and project locations, and responsibilities for our assistant directors and research support services; and it provided opportunities for improving our research program and our managerial efficiency. Although these changes were somewhat disrupting at first, the major impacts are behind us and we are back to normal again. Here are some of the changes that may be of interest to you:

- We have moved our headquarters office to 6816 Market Street, Upper Darby, Pa. 19082—a few blocks from our old office. Our new quarters are in the same building as those occupied by the State and Private Forestry Northeast Area Director's office.
- Our research support services are providing services to the S&PF Area Director for common activities such as personnel management, budget and finance, administrative services, and printing.
- Responsibility for Forest Service research programs in two additional states — Ohio and Kentucky — has been assigned to the Station. So we now serve 14 states.
- We have responsibility for 41 sep-

arate research projects. These are based at 13 different locations in 9 of the 14 states we serve.

- The Station now employs 375 people full-time. Just over 40 percent of our people are scientists or technical specialists in supporting fields. The remaining 60 percent provide a wide variety of support for our scientists as well as for the Upper Darby and field offices of the S&PF Area Director. In addition we have approximately 100 part-time employees.
- To meet the increased responsibilities of the reconstituted Station and of providing services to the Area Director, S&PF, we have strengthened our support services and have created new units in biometrics and information services.

Research Facilities

Our construction program is moving ahead nicely. Our new laboratories at Hamden, Conn., and Morgantown, W. Va., will be completed early in 1967. Some small additions were made in 1966 to our facilities at Delaware, Ohio, and Berea, Ky. The 89th Congress appropriated funds for planning new laboratories at Berea, Ky.; Burlington, Vt., and Durham, N.H., as well as for a major addition to our Forest Insect and Disease Research Laboratory at Delaware, Ohio. Plans for these new research facilities are well advanced.

Completion of the facilities under construction and those for which planning is in progress will be a major milestone for the Station. We will then have completed, with a few minor exceptions, all of the basic laboratory and office facilities authorized for us in the national program for forestry research.

Research Programs

Forest Service appropriations, as authorized by the last Congress, contained entries on both the black and red sides of the ledger for us. On the black side, besides receiving funds for planning the new facilities described above, we also received funds to start our wildlife-habitat research project at Morgantown, W. Va. On the red side, we lost some of the funds available last year for our research programs in engineering, log and tree grades, utilization, and recreation. Because of vacancies, program adjustments, savings from the reorganization, and other factors we have not had to reduce our staffs in these programs.

The reorganization provided opportunities for us to strengthen some of our projects through consolidation and program shifts.

- We have consolidated the recreation research formerly done by the Northeastern and Central States Stations. Our entire staff for this research is headquartered now at Syracuse, N. Y.
- The strong development of our marketing research at Princeton, coupled with a marketing research project at Carbondale, Ill., eliminated the need for a third unit at Berea. So we abolished that one and are replacing it with a new project in production economics.
- The former Central States Station had a substantial surface mine reclamation project at Berea, which now is assigned to our Station. We had been conducting research in this field at Kingston, Pa. before the reorganization. All of our reclamation research is being continued, but it has been pulled together into one project, with headquarters at Berea.

I hope that you will find our 1966 Report of interest and value. Please let us know if you have questions about any of the subjects discussed, desire copies of any of the publications listed, or have suggestions for improving our future reports.

—R. D. LANE,
Director

TIMBER MANAGEMENT

RESPONSIBILITY for three additional timber-management research projects was transferred to the Station in 1966, bringing the total number of such projects up to ten. All three of these projects were part of the former Central States Forest Experiment Station.

One of the three projects, located at Berea, Ky., is conducting research on the silviculture of mixed upland hardwoods. Here we are seeking ways to grow upland hardwood timber products more profitably. A large part of this program deals with control of natural regeneration and growth of mixed oaks and associated species. Four scientists are assigned to this project: Benjamin A. Roach, project leader, Ivan L. Sander, Martin E. Dale, and Rufus H. Allen.

A second project at Berea is conducting research on timber-related crops, especially Christmas trees, medicinal plants, and ornamental plants and plant parts. This relatively new project has studies under way on Christmas tree culture and the evaluation of exotics, hybrids, and native species for their suitability as Christmas trees in that region. Studies on other decorative and medicinal plants are just getting under way. Scientists assigned to this project include Arnold Krochmal, project leader, and Russel S. Walters.

The third project, located at Columbus, Ohio, deals with mensuration problems in eastern hardwoods. Studies under way there are aimed at developing techniques to predict growth, yield, and quality changes of trees and stands and at developing management-planning procedures for upland hardwoods. The scientist assigned to this project is Samuel F. Gingrich, project leader.

Several new scientists joined the timber-management staff in 1966. Arnold Krochmal, an economic botanist, transferred to the timber-related-crops project at Berea, from a position with the Agricultural Research Service. Krochmal holds a Ph.D. degree from Cornell University. John R. Donnelly, a physiologist, was appointed to a position in maple sugar research at Burlington, Vt. Donnelly holds an M.S. degree from the University of Michigan and is working on a Ph.D. from the same institution. Two new scientists were added to the genetics project at Durham, N. H.: Johannes P. van Buijtenen and Peter W. Garrett. Van Buijtenen holds a Ph.D. degree from Texas A&M University and comes to us from the Texas Forest Service. Garrett holds an M.S. degree from the University of Michigan and is completing requirements for a Ph.D. there.

In other changes, Grant Davis of our Kingston, Pa., strip-mine unit transferred to Berea, to become the project leader for the strip-mine project there.

Plans are developing to establish an environmental forestry project in the Upper Darby office. This project would have the objective of developing the special cultural techniques required to establish and grow trees and stands for maintaining and improving the human environment in urban and suburban areas of the Northeast.

Silas Little, who has done much of the planning for this project, has continued to complete the more important studies remaining from the silviculture

project at New Lisbon, N. J. A study of yellow-poplar reproduction in the Coastal Plain and Piedmont of Maryland and New Jersey has shown that the first-year catch of yellow-poplar seedlings was increased by seedbed treatment, but the increases were not usually needed. On disturbed seedbeds the catch ran up to 128,000 seedlings per acre, or 2 to 28 times the number found on undisturbed seedbeds. However, even the latter seedbeds usually had 2,000 or more seedlings per acre, which stocked 70 percent or more of the 2-milacre quadrats. Most of the reproduction apparently came from seed stored in the forest floor. Spots burned in the spring after seedfall and others burned in the fall—and screened to exclude fresh seeds—had as much reproduction as quadrats disturbed before seedfall and not screened.

Initial results from this study suggest that the following steps should be taken to regenerate yellow-poplar in the Coastal Plain and Piedmont: (1) create openings 1 acre or larger by harvest cutting or killing of existing trees; (2) kill back or eliminate the understory; and (3) disk or burn for seedbed preparation on the somewhat dry, borderline sites where oak or beech litter is deep enough to seriously reduce establishment of yellow-poplar seedlings. Seedbed treatments also seems advisable on sites having a low seed supply in the forest floor, especially if these are covered with dense herbaceous growth.

Sapsucker damage on an 11-inch d.b.h. paper birch. This tree was dying in August, apparently because of the band of closely-spaced feeding holes above and below where the bird is perched. Scattered holes, as seen near the bottom of the picture, are not usually fatal but cause defects in the wood.

SILVICULTURE OF SPRUCE-FIR

Orono, Me.

Spruce-Fir Growth Rates

Average growth rates by stand classes in the spruce-fir region were obtained from 766 plots in a 10-year growth study. The study was conducted in cooperation with 10 timberland companies in Maine. Overall average annual net growth was estimated to be

41.9 cubic feet per acre, with a 2.1 percent sampling error. Stand composition had the strongest influence on growth, which increased as the percentage of softwood species increased. Spruce and fir made major contributions to growth: 75 percent of the overall average, 86 percent in softwood stands, and 30 percent in hardwood stands.

The 10-year growth is slightly lower than the previously reported 5-year average, due to a slight increase in mortality and a decrease in ingrowth.

A New Sapsucker Survey Technique

The yellow-bellied sapsucker, which ranges over most of the important forest regions of North America, is known to damage at least 174 tree species. The feeding holes drilled by this bird kill some trees and may cause serious defects in the wood of trees that survive. However, little is known about the impact of this damage on the forest as a whole. A survey is now under way at the Orono project to appraise the impact of sapsucker damage in the spruce-fir type in Maine. This will be followed by research to devise ways to reduce the damage if protective measures appear to be justified.

In a preliminary study, it was found that sapsuckers could be called within visible range by imitating their drumming with a simple tool costing about 25 cents. This technique may be useful in later sapsucker-damage surveys or in subsequent control efforts. In a trial survey covering about 12 percent of a 4,000-acre area, we found that about one-half of the adult birds in the vicinity could be called within 100 feet on the first trip over the survey lines, and more than 80 percent of them could be called up in two trips. The calling procedure revealed five times as many sapsuckers as when lines were walked without imitating the drumming.

SILVICULTURE OF BEECH-BIRCH-MAPLE

Durham, N. H.

Harvesting Costs and Returns

An appraisal recently was made of roadside harvesting costs and returns in unmanaged old-growth northern hardwood stands on the Bartlett Experimental Forest. Four methods of cutting — selection, patch, diameter-limit, and commercial clearcutting — were undertaken on compartments large enough to simulate commercial logging operations. Tree-length skidding and multiproduct utilization were practiced in each type of cutting. Although the cuttings spanned a 14-year period, current local wages, equipment rates, and market prices were used to estimate harvesting costs and returns.

Dollar costs of logging under the four cutting methods averaged between $15.30 and $17.80 per hundred cubic feet of product harvested. Returns averaged between $26.80 and $38.20 per hundred cubic feet of product harvested. The differences in returns are attributable mainly to differences in the quality and value of the harvested products. Under selection and patch methods, the cuttings were stand-improvement operations, which removed many poor trees. Under diameter-limit and commercial clearcutting, the bulk of the cut was in better trees, which yielded products of higher value and, consequently, higher returns.

Stochastic Processes

Many biological phenomena are the result of a long series of interrelated events. The regeneration of a cut-over area, for example, may be considered a chain of events that begins with the initiation of flower buds on potential seed trees, continues through flowering, fertilization, seed development, seed dispersal, germination, and survival, and finally terminates with the

occurrence of a specific number of established seedlings in the reproduction.

Stochastic processes provide a mathematical technique of predicting the end result of such a series of events. This is done by specifying the probabilities of moving from each individual event to the succeeding event under a given set of circumstances. Such analyses should increase our knowledge of the biological process itself and ultimately provide the information needed to prescribe treatments that will give desired results from a particular set of original circumstances.

Theoretical applications of stochastic processes have been worked out for two phenomena in northern hardwoods. Regeneration of a clearcutting with paper birch can be expressed as a type of stochastic process called a simple absorbing Markov chain. The chain consists of 29 states or events beginning with the development or abortion of a potential ament and terminating with the occurrence of an acceptable stem, unacceptable stem, dead seedling, or non-germinate. With this information, it is possible to estimate the number of seedlings that will be obtained for various seed-dispersal distances, seedbed conditions, and sizes of clearcuttings.

The development of even-aged northern hardwood sapling stands can be represented by a two-dimensional process, which may be called the compound exponential process. Mean stand diameter, plotted over time, tends to follow a negative exponential distribution; number of trees at each diameter for any given mean diameter also can be expressed by the negative exponential distribution. Given the mean initial diameter and number of trees, we can estimate the numbers of trees in any diameter class at any future mean diameter. This process may help in evaluating the potential stocking of regeneration or sapling stands.

SILVICULTURE OF ALLEGHENY HARDWOODS

Warren, Pa.

Pruning Open-Grown Black Cherry

Epicormic branches that develop after pruning of open-grown black cherry trees have been under careful observation in a study now in its fifth year. During the first year, 4- to 6-inch trees pruned to 75 percent of their total height developed about 35 sprouts per tree, averaging 2 feet in length. In subsequent years a few of these sprouts have died off; but the survivors have grown larger.

Most trees pruned to 50 percent of their height had few or no epicormic sprouts after 1 year. There has been a slight increase in their numbers and size since then, but not enough to be considered serious. Even unpruned trees in the open sometimes develop sprouts. Pruning wounds are healing satisfactorily and cambium dieback has not been a problem.

It appears feasible and highly beneficial to prune black cherry trees in the small pole sizes up to 40 or 50 percent of their total height. Trees in less exposed situations could be pruned somewhat higher without adverse effects.

Pruning of black cherry trees growing in poorly stocked stands, such as those in this study, provides a means of salvaging these open-grown trees and developing stands of high potential value. If left alone, these heavily branched trees would produce only low-quality lumber. Pruning will also be a key treatment in any future intensive cherry culture, where trees will be grown at wide spacings to stimulate growth and facilitate such measures as fertilization, cultivation, and irrigation.

Herbicides for Weed Control Around Black Cherry Seedlings

The growth of black cherry seedlings is severely hampered where a dense herbaceous ground cover develops. A herbicide that would control grasses and forbs without damaging the tree seedlings would improve the chances for regenerating weedy sites.

Several herbicides have been tried for this purpose. Although none has been completely successful in single applications, partial or temporary control without damage to cherry seedlings was achieved with Dowpon or Amizine at 4 pounds per acre and with Ansar at 15 pounds per acre.

Amizine was the most effective of the three materials; when applied twice a year, black cherry seedling growth was equal to that on hand-weeded plots. Ansar doubled seedling growth, as compared to growth on untreated plots, but the growth was still less than on hand-weeded plots. Dowpon is most effective on grass. Dowpon and Smizine combined controlled weeds for a longer period than did either herbicide alone. The following have not shown much promise: Casoron W-50, Casoron G-4, Treflan, and Dymid.

SILVICULTURE OF APPALACHIAN HARDWOODS

Parsons, W. Va.

Site-Density Growth Relationships

A study of Appalachian hardwood growth as affected by density of residual basal area on two sites has been completed. The stands were on an excellent site (site index 85 for oak) and a fair site (site index 63 for oak). Three levels of residual basal area were studied on each site: 100, 80, and 60 square feet per acre in trees over 5 inches d.b.h. on the excellent site; and 75, 60, and 45 square feet per acre in trees over 5 inches d.b.h. on the fair site. Growth figures cover a 10-year period.

Growth differences due to site were large; but differences among the three residual stocking levels within each site were minor. Site differences may be summarized as follows: (1) average annual cubic-foot volume growth on the excellent site was 99 feet compared to 69 feet on the fair site; (2) average annual board-foot volume growth on the excellent site was twice that on the fair site; (3) d.b.h. growth rate of red oak on the excellent site was 1.6 times that on the fair site; (4) merchantable height of sawtimber on the excellent site was 10 to 12 feet more than on the fair site; and (5) species composition was appreciably better on the excellent site.

Residual stand density had no significant effect upon total cubic-foot volume growth on either site. When total volume production is the goal, these stands can be cut back to at least 60 square feet of basal area per acre on the excellent site and 45 square feet of basal area per acre on the fair site without loss in subsequent volume growth.

Although residual stand density had no significant effect upon board-foot growth, there was a trend toward greater growth at the higher densities on the excellent site. When sawtimber production is the goal, it would seem desirable to cut stands on the excellent site of no less than 75 square feet of basal area per acre. On the fair site, stands may be cut back to 45 square feet of basal area per acre. No appreciable log degrade from epicormic branching occurred at these recommended levels of residual density. It is important to keep in mind that these results apply only to forests where cutting is done periodically throughout the range of diameters above 5 inches.

SILVICULTURE OF MIXED UPLAND HARDWOODS

Berea, Ky.

Sapling Density-Growth Relationships

It is well known that density of stocking influences diameter growth rates. As stand density is reduced, diameter growth of residual trees increases until it reaches a maximum for the site. However, it is commonly believed that stand density has little or no effect on height growth. Three year's data from a study of growth in 7- to 10-year-old hardwood stands thinned to different degrees show that, at least in these young stands, density of stocking may influence height growth as well as diameter growth.

The degree of stocking achieved by 7-year-old natural stands of mixed oak, yellow-poplar, red maple, hickory, and other species on the Vinton Furnace Experimental Forest in southeastern Ohio was considered to be 100 percent. Plots were thinned to 10, 30, 50, and 70 percent; and control plots were left at 100 percent.

Analyses of 3 years' growth from 526 dominant and codominant trees show a high correlation between stand density and both height and diameter growth. Annual diameter growth over the period averaged 0.20 inch at 100-percent stocking, and increased to 0.25 inch at 50-percent stocking. Annual height growth averaged 1.3 feet at 70- and 100-percent stocking and decreased to 0.7 foot at 10-percent stocking.

Intermediate and suppressed trees also increased in diameter growth and declined in height growth at lower densities, but the amount of change was much less than for dominants and codominants.

To achieve maximum diameter growth without sacrificing height growth, these young stands will have to be thinned to a rather carefully controlled density. Total release of only a few crop trees per acre will result in loss of height growth on those trees. Furthermore, intermediate and suppressed trees cannot be relied on as future crop trees, even in young stands. Their growth is too slow and their response is too weak, regardless of the degree of thinning applied, to count on their becoming part of the main stand.

Growth of Oak Seedling Sprout Reproduction

After a regeneration clearcutting in mixed oak timber, most of the oaks in the new stand develop as new sprouts from reproduction that was present before the cut was made. However, the number of new stems that develop successfully is usually much less than counts of advance reproduction would indicate. We observed that many of the new sprouts were small, apparently too weak to compete, and soon disappeared from the new stand.

To study the factors affecting sprout vigor, a number of stems of oak advance reproduction in a new clearcutting were measured and cut off, the stubs were tagged, and new sprout growth was measured if it occurred. Ninety-three percent of the cut stems sprouted. Two-year results from this study indicate that vigor of the new sprout is directly related to the size of the original stem.

On our typical oak sites, it appears that new stems must average 1¾ to 2 feet of height growth per year for at least 3- to 5-years if these stems are to become dominant in the new stand. Our data show that stems of oak advance reproduction must be about 1 inch in diameter or larger before new sprouts from them will attain this rate of growth. Possibly a somewhat smaller diameter will ultimately prove acceptable; an unusually severe freeze in May 1966 killed 6 inches to 1 foot of the growing tips, and probably reduced

the average 2-year height correspondingly.

Nevertheless, these data imply that when oaks are desired in the new stand, a sufficient number of advance stems of oak reproduction about 1 inch in diameter near the ground line must be present on the area before the harvest cut is made.

TIMBER MEASUREMENT AND MANAGEMENT PLANNING

Columbus, Ohio

Forecasting Stand Growth and Yield

There is much tree-to-tree variation in growth that cannot be explained by ordinary area or plot measurements. An intensive effort is being made to quantify some of the factors that cause these variations in the growth of individual upland hardwood trees so that growth may be predicted more accurately, and to provide better guides for thinning around individual trees. Principal variables under study are species, various measures of tree density, spatial arrangements of competitor trees, tree size and dominance index, and site quality.

Preliminary results of the study show that upland oak stands of natural origin exhibit very irregular spacing or clumping in young stands. The greater the mixture of species, the greater the clumping. Spacing becomes more regular with increasing stand age. Among the more common upland oaks, the red oak group grows faster than the white oak group. Also, white oak generally grows faster when mixed with other

An optical dendrometer of high precision is used to obtain volume and growth estimates on selected sample trees.

oaks and hardwoods than when growing in pure stands.

Computer programs are now being developed that will simulate stand growth based on the individual tree relationships. The results of these programs will be compared with the growth of several hundred research plots located throughout the hardwood region.

GENETIC IMPROVEMENT OF NORTHEASTERN TREES

Durham, N. H.

Hybrid Poplar Clonal Tests

A hybrid poplar clonal test was established over a 5-year period beginning in 1949 on two upland sites on the Hopkins Experimental Forest in Massachusetts. One site was flat; the other was a northeast-facing slope about 175 feet higher in elevation and 2,000 feet distant. The clonal plots were thinned and measured 4, 9, and 15 years after planting. Data are now available for 25 of the 250 clones included in the study.

Clonal selections were made on the basis of an arbitrary average height 20 percent or more above the average of all clones at the end of 4, 9, and 15 years on each planting site. Ten clones would have qualified at 4 years and four clones at 9 years on the basis of their superior average height growth. The following six clones, representing 4 parental combinations, were at or above the selection level after 15 years:

NE- 20 *P.* cv. Charkowiensis x *P.* cv. Caudina

NE- 21 *P.* cv. Charkowiensis x *P.* cv. Caudina

NE-207 *P. deltoides* x *P. trichocarpa*

NE-216 *P. deltoides* x *P. trichocarpa*

NE-264 *P.* cv. Angulata x *P.* cv. Volga

NE-300 *P.* cv. Betulifolia x *P. trichocarpa*

Three of these (20, 21, and 300) met the selection requirement on both sites; two (207 and 216) were above the selection level on the slope site only and one (264) was above the 20-percent level only on the flat site. It should be noted that of the six clones that met the selection criterion after 15 years, three (20, 207, and 264) were slow-starters that would not have been selected in either the 4th or the 9th years. Early selection in this case would have left only three clones for selection on the basis of a 20-percent difference in average height.

These results illustrate the need for synthetic multiclonal hybrid varieties that will provide sufficient genetic adaptability to the wide variation in growing conditions within even a very limited locality. The results also emphasize the need for caution in the early selection of clones. Selections should probably be delayed until the clones reach about half of their rotation age.

Fifteen-year studies of 250 clones will be completed in 1968. On the basis of six selections for height growth in this 25-clone example, we may expect to have 50 to 60 select clones for use in synthetic multiclonal hybrid varieties.

White-Pine Weevil Resistance

For a number of years we have been interested in more intensive research on the selection and/or development of white pines resistant to the white-pine weevil. Dr. J. P. van Buijtenen, who joined our staff in September, will devote most of his time to this problem. A rather practical approach will be taken, placing emphasis on full utilization of the considerable body of in-

formation available about the biology of the insect and the defense mechanisms of the host. In addition, a number of basic studies on the nature of host resistance are under consideration.

SUGAR MAPLE SAP PRODUCTION

Burlington, Vt.

Sap-Production Techniques

Results of a large-scale comparison of vented versus non-vented suspended tubing for collecting sap showed that, under the particular study conditions involved, non-vented lines outyielded vented lines by a surprising 43 percent. Vacuum on the non-vented lines, caused primarily by the weight of the sap in the line, was directly related to increases in yield during both heavy and light flows.

Results from a new study of the relationship of fall to spring sap yields from the same tree confirmed earlier findings that fall tapping reduces the volume of spring flows. Spring sap sugar percentages were not affected, but fall sap was only 65 percent as sweet as spring sap.

The relationship between taphole depth and sap and sugar yields was more closely identified in a study of xylem tissue age. Yields were segregated by 1-inch segments to a depth of 6 inches, and the average age of each segment was determined. Sap sugar content was highest in the outermost segment where the xylem is youngest; sugar content decreased with increasing tissue age (or depth of segment). Sap volume production increased with depth up to a maximum that occurred in xylem tissue between 30 and 40 years of age. At ages (or depths) greater than this, volume of sap production decreased.

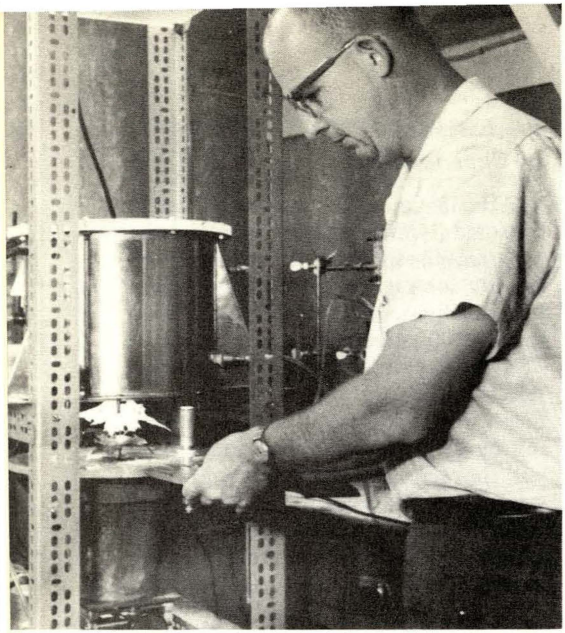
Production of Superior Genotypes

After 3 years of concentrated effort by some 70 fieldmen in 6 states, the program to select trees of *Acer saccharum* for high sugar production was successfully terminated. Out of more than 21,000 trees that were examined over the 3-year period, 236 trees were selected. Slightly more than half of these were given a final field screening by geneticists; the remaining trees will be screened during the coming sap season. Then 40 to 50 of the best candidates will be chosen for sources of clonal material and for breeding stock.

In a study of the relationships of *A. saccharum* and *A. nigrum,* the wide morphological variations observed between the two taxa suggests that specific ranking may be justified for *A. nigrum.* Preliminary results of reciprocal controlled pollinations made between individuals of the two taxa indicates that crossability barriers may be present when *A. nigrum* is used as the female parent.

A study of dichogamy in *A. saccharum* has shown that conditions of protogyny and protandry were equally represented in the population investigated. Among protogynous trees a slight overlap in blooming occurred between flowers of opposite sexes under average temperatures; the period of overlap became longer with lower temperatures. Higher temperatures increased the tendency toward complete dichogamy through earlier desiccation of stigmas. Abnormally high or low temperatures seemed to exert little influence on the duration of blooming periods of flowers of either sex among protandrous trees.

An investigation of factors influencing seeding and fruiting in *A. saccharum* indicated that the species is self-compatible to a variable degree. Seed set from self-pollinated flowers among individual trees ranged from



Evaluating a sugar maple seedling for apparent photosynthesis as related to different levels of moisture and temperature.

8.1 percent to 27.1 percent. Cross-compatibility was found to vary significantly between trees, although variation in seed set to given parental combinations could not be consistently related to either male or female parent. Self-sterility and cross-sterility apparently are related phenomena, as shown by a statistically significant correlation of rankings of female parents for seed set to self-and cross-pollination. The species was found to be highly agamocarpic. Agamospermy appears to be of little significance in the seeding habits of *A. saccharum*.

Sugar Maple Establishment

A cooperative study is being conducted with the University of Vermont Forestry Department to determine the effects of various moisture and nutrient levels on growth of sugar maple seedlings. Results of this research will provide a better understanding of basic sugar maple seedling growth requirements, leading not only to greatly improved nursery stock, but also to successful establishment of field outplantings.

Results obtained at the end of three growing seasons indicate that height and diameter response are positively related to soil moisture level. Total height of seedlings grown in soil maintained near field capacity was approximately three times that of those grown in soil with water content kept near the wilting point. Nutrients, applied once at the beginning of the experiment, also influenced seedling growth. Growth was best in those soils that received a medium dose of nutrients.

CHRISTMAS TREES; OTHER DECORATIVE & MEDICINAL PLANTS

Berea, Ky.

Christmas Trees

An early spring, pre-planting site-preparation treatment of mowing followed by application of Simazine has given good weed control around

Christmas trees. Weed control lasted throughout the growing season.

Early survival and growth data from a number of species trials have shown that Scotch pine and white pine have promise for Christmas tree use in Kentucky. The several sources of eastern white pine (Kentucky, Michigan, New York, North Carolina, and West Virginia) are about equal in performance: good survival but somewhat slow in growth rate. The domestic strains of Scotch pine, primarily from the Northeastern States and Canada) have survived well and grown fast. The Scotch pine races *armena* and *iberica* also have survived well but they are slower growing.

Among the other species being tested, Norway spruce (sources—Austria and Poland) are surviving very well but their growth is slow. Various Douglas-fir sources are growing equally well, but the variety *glauca* sources from Arizona and Colorado have had higher survival rates than the others. Variety *caseia* from British Columbia has also survived well.

Decorative and Medicinal Plants

Appalachian forests contain many plants that have potential value for decorative or medicinal purposes. Some of these materials are being harvested and sold in commercial quantities, but the industry has never been fully developed.

The need now is to determine the variety and type of decorative and medicinal plants available and to learn where they grow, and how they can be maintained, improved, propagated, and grown in the forest and then harvested without destroying the plant population. Studies of these plants will be undertaken now that a second scientist has been assigned to the project.

Bittersweet (Celastrus scandans L.) is a common plant of the Appalachians that is sometimes sold along roadsides in late fall for decorative purposes.

WATERSHED MANAGEMENT

TWO additional watershed-management projects were assigned to the Station in 1966 as a result of the reorganization that closed the headquarters of the Central States Forest Experiment Station. This brings the total number of watershed-management projects at the Station up to six.

One of these projects, located at Columbus, Ohio, deals with storm runoff in the Allegheny - Cumberland Plateau. Research under way there is aimed at clarifying the phenomena of subsurface stormflow, with the eventual goal of developing treatments that will reduce storm runoff and increase deep groundwater storage. Scientists assigned to this project are Ronald Z. Whipkey, project leader, and Gerald M. Aubertin.

The second project, at Berea, Ky. deals with strip-mined area restoration. Through studies of strip-mine engineering, hydrology, and revegetation, we hope to develop techniques that will minimize the mining damages to natural resources and will enable restoration of these lands to an attractive and productive condition. Scientists assigned to this project are Grant Davis, project leader, William T. Plass, William A. Berg, Willis G. Vogel, Willie R. Curtis, and George P. Williams.

A number of personnel changes have occurred during the past year. Edward S. Corbett transfered from the Pacific Southwest Station to take over the municipal watershed studies in Upper Darby, Pa., replacing Irvin Reigner, who was transferred to our Washington office. Corbett holds an M.S. degree from the New York State University College of Forestry at Syracuse. George P. Williams, civil engineer, transferred from the Carson National Forest in New Mexico to fill a vacancy in the strip-mine restoration project at Berea, Ky. Willie R. Curtis, hydrologist, also joined the strip-mine project, replacing William D. Striffler, who resigned to accept a position at Colorado State University. Curtis was formerly with the North Central Station; he holds an M.S. degree from the University of Minnesota. And Grant Davis transferred from the Kingston, Pa., unit to replace Robert May as project leader of the strip-mine restoration research in Berea. May is now in the Washington office of the Forest Service. In New Hampshire, George Hart left the watershed project to accept a position at Utah State University.

WATER YIELD IMPROVEMENT IN NEW ENGLAND

Durham, N. H.

Watershed Treatment

In December 1965 a 39-acre south-facing watershed on the Hubbard Brook Experimental Forest was clear-cut. The second-growth northern-hardwood timber was not removed from the area; instead, the vegetation, including all woody plants, was felled and left in place. An herbicide (Bromacil) was applied by helicopter the following June to help maintain a vegetation-free condition for several years.

During the first summer, the Brom-

Aerial view of the 39-acre clearcut watershed on Hubbard Brook Experimental Forest. Most of the slash and down timber is buried under 2 to 3 feet of snow. The uncut watershed (105 acres) to the right of the clearcut is the control.

acil eliminated all shrubs, seedlings, and herbs on the forest floor and reduced sprout growth from the cut stumps. This treatment was considered effective in eliminating transpiration from the watershed. Since impermeable bedrock in the watershed precludes water loss to deep seepage, the difference between precipitation and runoff should be evapotranspiration.

Preliminary calculations from 1 year's results under this clearcutting treatment show that it is possible to attain water yields of 14 area-inches more than the amount that would be expected if the watershed were not treated. Because studies conducted elsewhere indicate that north-facing watersheds should produce greater streamflow increases from clearcutting than south-facing watersheds, water yields greater than 14 inches are plausible. Such an increase would be important because it would come in late summer when streamflow is normally low and water is most needed.

Evapotranspiration for the clearcut watershed (before cutting) and two adjacent check watersheds averaged about 21 area-inches per year. This value agrees remarkably well with a potential evapotranspiration of 22 inches calculated for this area by Thornthwaite's method. The substitution of evapotranspiration for precipitation minus runoff seems justified. Although evaporation undoubtedly increased from the treatment, the magnitude and dominant role of transpiration over evaporation under normal forest conditions is readily seen from this experiment. There was no increase in suspended sediment as a result of the treatment.

STREAM REGIMEN IN NEW YORK

Syracuse, N. Y.

Solar Radiation Relationships

An aerial tramway system designed to facilitate studies of the spatial variation in reflected shortwave radiation from the forest canopy has proved highly satisfactory after a full year of operation. Approximately 40,000 measurements have been taken during this period, on five different tramways.

The tramway system consists of two steel towers erected to extend above the canopy of trees over which measurements are desired. A 100-foot cable tramway between the two towers enables a cart containing a solarimeter or other meteorological instruments to be moved across the tramway to measure variation in reflected shortwave radiation or other variables. The tramway cart is powered by an electric winch with variable speeds; instrument output is recorded at the base of one of the towers. An analytical model has been developed using linear systems analysis techniques to characterize instrument response in time and space for the various tramways.

Albedo measurements above a snow-covered red pine canopy at Warrensburg, N. Y., were obtained with the tramway system during 1966. Measurements were taken when the canopy was completely covered with about 3 inches of snow. Albedo at mid-day under cloudy sky conditions was 0.194, with a coefficient of variation of 3.53 percent. This may be compared with an albedo of 0.074 and a coefficient of variation of 5.75 percent above a snow-free canopy at mid-day under similar cloud cover.

Trail Erosion in the Adirondack Mountains

A study of the increasing impact of recreationists upon forest and watershed values in the high-country of the Adirondack Mountains was begun during the past year in cooperation with the New York State College of Forestry at Syracuse. Increasing traffic along mountain trails has induced erosion on the steeper slopes and has led to site deterioration in some places.

Thirty peaks were visited in 1966, and observations were made on the severity of damage at each. Past disturbance, intensity and length of recreation use, and various site factors all seemed to affect the damage. Vegetational-ecological analyses will be made of selected areas in 1967 and standard erosion-control techniques will then be tried on these plots.

WATERSHED CORRELATION AND SYNTHESIS

Upper Darby, Pa.

The year's effort was marked by 5 publications, 8 manuscripts accepted for publication, and 3 in preparation. At least four papers tried to answer the continuing question, "What is the effect of forest cutting on water yield?" Specifically, we have tried to answer it in respect to water yields in Appalachia, in respect to the effects of even-aged management, and in respect to the effects of urbanization that follow forest cutting.

Other papers have dealt with streamflow in the Northeast, the use of phenoxy herbicides on forested watersheds, and estimation of evapotranspiration from the riparian zone. We also compiled an annotated bibliography of watershed-management research at this Station, containing 156 literature references.

Our major effort in this direction was preparation of a Station Paper (now in press) under the title "Increasing Water Yield in the Northeast by Management of Forested Watersheds". Here we note the substantial

increases in water yield that can be expected from clearcutting well-stocked stands on watersheds primarily devoted to water yield, and the costs of maintaining these areas non-forested and soil-stabilized. Partial cuttings under even-aged management in a sustained timber-yield program will yield a small percentage increase in annual water yield, but still a sizeable increase in terms of water volume. Partial cuttings under all-aged management, and thinnings, may have only a negligible effect on water yield. Also discussed are the effects on water yield of tree planting, fire, insects, diseases and long-term forest protection. Safeguarding water supplies is stressed.

During the year we embarked on one new venture — a study of the trends in long-term streamflow records in the East in relation to land-use changes. Substantial progress was made in our Station-wide study of hardwood and conifer humus accumulations and their hydrologic implications.

Results of last year's treatment of a Newark, N. J., watershed with herbicide, and of a Baltimore, Md., watershed by cutting the riparian vegetation, are beginning to show up in increased water yields. At State College, Pa., another study of the effects of vegetation removal on water yield is getting under way. First, the lower one-third of an experimental watershed—mostly riparian area—will be clearcut. The remaining two-thirds of the watershed will be clearcut in one or two steps at 2-year intervals. The cutover areas will be sprayed with herbicides to hold down vegetative growth in the years between cutting operations.

All the studies mentioned above are cooperative undertakings either with university people or with municipal watershed managers. Their contributions greatly increase the effectiveness of this project.

FLOODS AND WATER YIELDS IN THE NORTHERN APPALACHIANS

Parsons, W. Va.

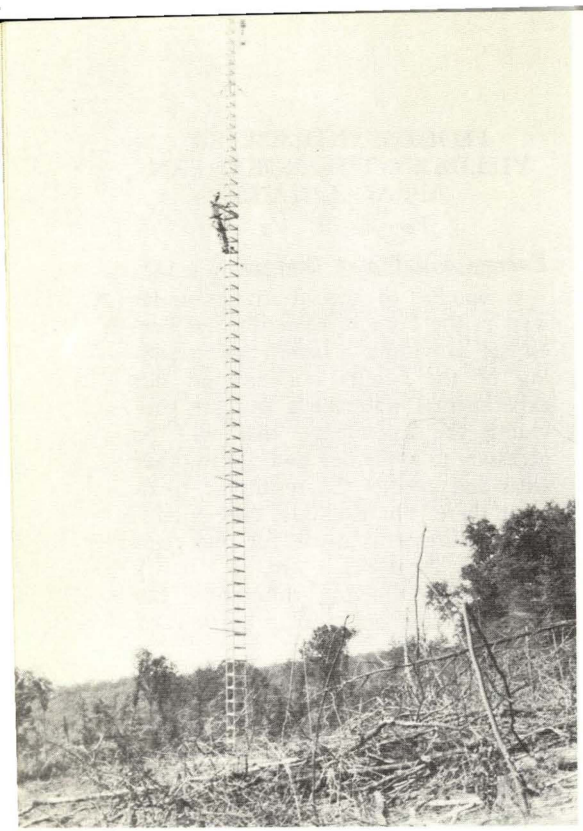
Energy and Water Budgets

A number of special studies under way on the Fernow Experimental Forest are providing a better understanding of the results obtained on our experimental watersheds and are providing the knowledge that will be necessary to apply our findings to other areas and predict the results of treatment there. For example, energy-budget measurements made for one clear day (July 21, 1966, 7 a.m. to 7 p.m.) reveal the following differences between forested and clearcut portions of one watershed:

	Forested gm cal/ sq cm	Cleared gm cal/ sq cm
Shortwave, down	674	674
Shortwave, up	126	82
Shortwave, net	548	592
Longwave, down	272	274
Longwave, up	363	410
Longwave, net	—19	—136
Allwave, net	457	456
Soil heating	19	104
Vegetation heating	15	2
Convection loss	85	99
Residual for evapotranspiration	338	251

This energy is sufficient to evaporate 0.23 and 0.17 inch of water on the forested and cleared areas, respectively. The difference, 0.06 inch, is very close to the 0.05 inch determined by streamflow analysis as the average daily increase from the clearcut area in July 1966 for the watershed on which these measurements were made.

Eleven years of records on the Fernow Experimental Forest were analyzed, using accepted procedures to determine the water budget. We made estimates of potential evapotranspiration for each day in the growing season. This represents the amount of



Tower on the Fernow Experimental Forest for measurement of energy budget. A similar tower is located in an uncut portion of the watershed to enable comparison of the energy budget on the two areas.

water that would be evaporated and transpired if plenty of water were available. Estimated actual evapotranspiration averaged more than 95 percent of the potential; even in the driest year in the period, actual use was more than 90 percent of the potential. This indicates that water is seldom limiting under our conditions. Knowledge of relationships like these should assist in application of research results to other areas.

The water-budget study also indicated that some of the water yield on our watersheds seeps through the underlying rocks to groundwater and is not measured at our weirs. The amount varies considerably by watershed. We believe that our treatments increase this groundwater component as well as the measured streamflow, and that the total increase in yield is somewhat greater than the amounts reported.

MANAGEMENT OF STORM RUNOFF

Columbus, Ohio

Subsurface Stormflow

In the Allegheny-Cumberland Plateau and in much of the mountainous terrain of the Northeast, direct runoff from forested watersheds comes almost wholly from subsurface stormflow. Surface storm runoff is relatively unimportant. The forest floor litter intercepts and dissipates rainfall energy and allows easy entry into the permeable surface soil. From here, infiltrated water follows the path of least resistance to the nearest stream channel.

The large rates and volumes of water seeping from a given mass of soil cannot be accounted for by the simple percolation of water through the soil material, even though depth of soil to a fine-textured, impermeable horizon may be as little as 18 to 24 inches. Much of this water seems to flow through the many interconnected cracks and root holes.

For example, on large sprinkled plots, seepage occurred from rootholes and cracks as deep as 32 inches below the soil surface, less than 1 hour after sprinkling began. To reach these outflow points, this water had to travel laterally through 4 feet of unwetted buffer strip bounding the plot. Be-

cause the inherent permeability of the soil was less than 4 inches per hour when saturated and even less when unsaturated, we can only speculate that the resistance to wetting causes the infiltrated water to pond, giving positive hydraulic pressure. This breaks down the outflow barrier and forces water into available large cracks and openings.

In another observation, water was ponded in a small depression in fine-textured silt loam. In less than 100 minutes after ponding, flow appeared at an exposed downslope face from large root-hole openings about 48 inches below the soil surface. To reach the outflow points, this water had to travel vertically through a 36-inch tight clay loam layer; this clay has a saturated permeability of less than 0.1 inch per hour.

More intensive study of soil micropores and channels is under way to further our knowledge of water movement through forest soils. The channels caused by soil compaction immediately adjacent to growing tree roots and the resulting pipe-like condition which results after the root has decomposed will receive special attention. Eventually we hope to develop practical treatments that will delay lateral subsurface runoff and cause this temporarily detained water to find routes to deeper groundwater storage.

MINE-SPOIL RECLAMATION

Berea, Ky.

Our coal-mine spoil reclamation research project is concerned with the mine-spoil problem through the whole of Appalachia—from Pennsylvania to Alabama—though the field studies remain concentrated mainly in Pennsylvania and Kentucky. The project involves surveys of existing conditions and research studies in hydrology, engineering, and revegetation.

Surveys of Eastern Kentucky

Two surveys are in progress in the eastern Kentucky coal fields—one to determine the acreage disturbed by strip mining for coal and for refractory clays, and one to provide information about the physical dimensions of the spoil banks, on the physical and chemical properties, on the chemical properties of impounded water, and on the character and density of vegetation. The acreage survey is based on aerial photographs flown in 1964. These show 55,100 acres disturbed by coal mining, 1,500 acres disturbed by clay mining, and 3,900 additional acres disturbed by haul roads serving the mines. A series of six publications, one to describe the mining disturbance in each of six districts, is in preparation.

Hydrologic Studies

These studies include a sampling of almost 200 streams in eastern Kentucky in 1966 to obtain water-quality data; 2 years of sampling and measurement of the quality of water flowing from different parts of stripped areas; and a before-and-after study of the water regime on a small undisturbed watershed that is destined for stripping within a few years. In all these studies the general objective is to correlate water quality, water quantity, and storm peaks with the amount and characteristics of the mining disturbance.

Engineering

In contour stripping of mountainous regions, slides occur in about 12 percent of the outslope area. Slides result from an excess of internal water in a bank that has been overloaded or over-extended in relation to the original slope of the land. In one of our studies, allowable widths of fill benches for a range of original slopes were calculated; these widths range from 100 feet for 15-degree slopes to 35

Plot of weeping lovegrass on acid spoil (pH 4.0). Other species seeded on soil in foreground failed to establish.

feet for 30-degree slopes. Few slides will occur if these indicated widths are not exceeded. On slopes steeper than 30 degrees, overburden cast upon them may never stabilize.

Based on the results of this study, regulations governing bench widths according to original slope were incorporated into Kentucky's new strip-mine law.

Revegetation Studies

Although trees have been used in most revegetation efforts on mine spoils, to obtain a permanent protective cover, there are situations where establishment of herbaceous cover is desired for more rapid soil stabilization, reduction of stream sedimentation, or aesthetics. In trials of many herbaceous plants on a variety of spoils, we have found weeping lovegrass *(Eragrostis curvula)* to be one of the most acid-tolerant and effective species. It has developed good cover the first growing season in spoils as acid as pH 4.0, and it will grow during midsummer when many other cool-season grasses lapse into a semi-dormant condition.

Fifth-year remeasurements in a study of 60 hybrid poplar clones planted on six widely different bituminous spoils in Pennsylvania confirmed our earlier report (1964) that many of the clones will survive and grow on spoils that are not excessively acid. On the two most acid sites, where original acidities were pH 3.1 and 3.3, performance has been poor. On the other four sites, where original acidities ranged from pH 3.6 to 5.7, survivals of the 10 best clones range from 64 to 98, and mean heights from 9 to 20 feet. Some clones on the best site now exceed 30 feet in height.

Eleven coniferous species and three hardwood species planted in 1963 on strip-mine spoils in the Pennsylvania anthracite region are exhibiting generally adequate survival and are making good growth. Survival has been significantly better on graded than on ungraded spoils, and significantly better on spoils composed of the deeper-lying materials than on spoils composed of the surface overburden of glacial till. Survival averages about 45 percent on the glacial till, and ranges from 58 percent to 87 percent on the graded phases of the other spoil types.

Survivals of the same species planted at the same time on deep-mine spoils are generally poor. This material, composed largely of broken rock, is a very inhospitable growing medium for plants.

FOREST ECONOMICS

REGIONAL SUPPLY-DEMAND RESEARCH

OUR ECONOMICS research is aimed at identifying the location and specific nature of forestry economic problems in the Northeast and translating this information into forms suitable for benefit-cost evaluation of forestry assistance programs and forest-management practices in various sections of the Northeast. One goal is to develop economic simulation models that will aid forest administrators in decision-making.

Two papers dealing with the development of these models were published by Station economists in 1966. One on *Economic base projections for river-basin planners,* by Robert S. Manthy, discusses four methods used to project industrial activity in river basins. Three of these methods make independent projections to derive future consumption requirements for a limited natural resource. These requirements are then compared with independently derived projections for supply of the resource. The other method is a closed dynamic simulation model. In this type of model the projection of demand can be tied to the projection of supply. We are developing these models further so we will be able to relate the need for government programs to the costs of a particular program and show how programs can be altered to improve management of the resource.

In another publication, *Projecting regional timber products production,* by Perry R. Hagenstein, the techniques of analyzing timber requirements that can be drawn from a particular region and those better obtained through interregional trade are discussed. Regional differences in the costs of growing, manufacturing, and distributing timber are important variables in the analyses. In nearly all regional economies, major adjustments must be made for interregional trade to equate production and consumption.

As part of a general analyses of black walnut timber-management needs, the present black walnut timber resource and the outlook for demand and supply of walnut timber were reviewed in a report, *Black walnut culture,* published by the North Central Station. Black walnut is found throughout most of the eastern United States. The latest appraisal showed that there is now about 2.7 billion board feet of sawtimber. Quality is generally low; only about 10 percent of the sawtimber volume is in trees 19 inches d.b.h. and larger.

Today the annual cut of high-grade logs exceeds the annual increase in quality material, and the outlook for high-quality walnut timber in sufficient quantity to supply current and increasing levels of demand is not promising. In the long run, intensive management of our present resources and the establishment and management of walnut plantations are the only sure ways to provide increasing quantities of high-quality walnut timber.

A special inventory was made of the black walnut timber on non-forest land in Kentucky. These were trees growing in fence rows, in open pastures, and along streams in blocks or strips too small to be classed as forest land.

Inventory results will be reported in the coming year. Preliminary results show that the walnut sawtimber volume on this non-forest land is almost a third as great as the volume on forest land. This volume would be even greater except that 40 percent of the sawtimber-size trees were not merchantable under present standards.

The market for fireplace wood in Connecticut was studied and reported on (our Research Paper NE-51) in a cooperative study with Yale University. Nearly two-thirds of the State's total roundwood output is firewood. In contrast to the declining use of wood as a fuel in most parts of the country, in Connecticut firewood use has remained nearly constant during the past decade. The decline in the use of wood as a primary source of heat has been offset by an increase in the consumption of fireplace wood. Today fireplace wood has become one of the most important timber products of Connecticut's forests. In urban areas most of it is produced by a few large-scale retailers who obtain the wood from land-clearing, tree-removal, or other noncommercial forest-management activities of the seller.

ECONOMICS OF TIMBER GROWING

One of the important goals of economics research for many years has been to improve the amount and quality of information available about the investment potentialities of forestry. Recent developments in timbermarketing—including the increased demand for certain species and the tightening of the woods labor market—have further emphasized the need for economic information. One outstanding need is for combining economic evaluation with biological information to achieve maximum effectiveness of research findings—through more rapid application once the economic justification is fully validated.

Our program of economic research is directed toward just such goals. Studies now are in progress and are making use of both published and unpublished forest management and protection data.

Results of research along these lines, published this year in our Research Paper NE-45, gives *Economic guides for blister rust control in the East.* Control of blister rust has been carried on since about 1910 in the eastern United States. In most areas blister rust is no longer a serious threat, but guides and standards are needed for determining the conditions under which control is worthwhile.

The essential decision in blister rust control work is whether to undertake a control treatment now or to delay treatment until the next examination, perhaps 10 years hence. Elements used in the evaluation procedure include the observed infection rate, climatic hazards, pine density, site index, stand-age, years to harvest, and control cost. The evaluation procedures lead to an estimate of the value saved by immediate control measures. Immediate control is economically justified when present worth of value saved exceeds the cost of control.

A similar report by Robert J. Marty on *How Much you can afford to spend in controlling forest insects?* was also published. This discusses ways to evaluate insect-control procedures. Schedules of control costs and values saved are developed. The evaluation procedures help determine the course of action to take when a choice must be made among several control projects.

Another area of research in this project deals with evaluation of reforestation and stand-improvement projects. One study being conducted in cooperation with our timber-management research projects concerns growth and financial maturity of some of the more important hardwoods of the re-

gion. Quality and the projected increase in quality resulting from management practices are being analyzed to arrive at the economic aspects of hardwood timber management.

In other work we analyzed 15 common oak-hickory stand classes found in the Appalachian area. By providing a basis for rating and comparing investment opportunities, these appraisals indicate what kinds of projects to favor in planning a program for stand improvement and stand conversion. The analyses enable projects to be rated on the basis of their expected productivity so that those that have the highest rate of return can be financed first. Results will be published in 1967.

Because timber-stand improvement and reforestation are so important to the total timber-management program on the National Forests, a general guide was prepared, which outlines procedures for rating and comparing proposed stand-improvement and reforestation projects (U. S. Dep. Agr. Handbook 304). A computer program for the rate-of-return computation is presented in the report.

The accomplishments of the Agricultural Conservation Program (ACP) in southeastern Ohio, as related to the Conservation Needs Inventory of that area, are discussed in a publication now in press (our Research Paper NE-65). At the present rate of accomplishment, only about 4 percent of the timber-culture work and 8 percent of the tree planting estimated as needed by the Conservation Needs Inventory by 1975 will be achieved under ACP.

The report charts the rather erratic rate of annual accomplishments due to the individual forest practices, and emphasizes the need for close stewardship of the program. It also reveals that the mere inclusion of forestry practices in the ACP is no assurance that the problems affecting our small timber stands are being adequately confronted.

The report emphasizes the varying problems that are due to the quality and extent of open land as related to tree planting; and the quality, age, and extent of the forests as they influence the need for timber-culture work. Within the 26 southeastern Ohio counties, differences in conservation needs are evident. In one group of counties where there is considerable marginal grazing land, the need was for tree planting, whereas in some more heavily forested counties the recognized need was for effective timber-culture work. Though the ACP recognizes these differences, even on a county level, the need for greater emphasis on conservation efforts, both public and private, is evident.

FOREST SURVEY

A COMPREHENSIVE re-inventory of the timber resources in the 14-state Northeastern area is more than half complete. Six states, which account for 55 percent of the forest area in the region — New Hampshire, Vermont, Pennsylvania, Maryland, West Virginia, and Kentucky—have been resurveyed, and field work for the second surveys of New York and Ohio is under way.

Resource bulletins reporting results of these resurveys have been printed for New Hampshire and West Virginia; a report for Maryland is ready for printing; and a report for Kentucky is ready for editing. Resource reports based on the resurveys of Pennsylvania and Vermont are being written.

FOREST RESOURCES

Results of the recent re-inventories of Kentucky, Pennsylvania, and Vermont show that commercial forest land in these three states combined has increased about 8 percent between surveys (1948-66). The increases ranged from 2 percent in Kentucky to 15 percent in Vermont. Trend analyses indicate that the acreage of forest land in all three states is still on the rise, due mainly to idle farm land reverting to forest.

Growing-stock volume in the three states has increased—from 4 percent in Kentucky to 30 percent in Pennsylvania. Sawtimber volume also increased —from 1 percent in Vermont to 13 percent in Pennsylvania.

Significant shifts in timber size have taken place since the three initial inventories. There have been significant volume increases in trees of less than 17.0 inches d.b.h., but the volume in larger trees—the size preferred by sawmills, veneer plants, and other wood-using industries cutting for high-grade products—has declined.

In all three states, net annual growth exceeds annual cut. In Kentucky and Pennsylvania the annual growth of all growing stock is about three times the annual cut, but in Vermont the growth is only about one and one-third times the cut. The growth of sawtimber also exceeds the cut, but by lesser amounts. In fact, for some of the heavily used species the cut of sawtimber exceeds the growth.

New York

Field work for the resurvey of New York has progressed according to plans. For three geographic units, including 28 counties in the western part of the State, the resurveys were completed in 1966. Resource statistics for these three units and counties will be available by June 1967.

Field work will continue in the northern part of the State in 1967, and the survey of the rest of the State will be completed in 1968. A comprehensive state statistical and analytical report will be prepared in 1969. The New York Conservation Department has provided for an intensification of field work in various units of the State. Additional funds for intensification in the 13-county Appalachia area have been obtained under the Appalachian Development Act of 1965. This will provide more precise county resource

data for the many users of survey information.

As a part of the resurvey, and in cooperation with the Conservation Department, a survey of 1967 timber-products production for the State will be made in 1968.

Ohio

We are continuing field work for the resurvey of Ohio into the winter months in an attempt to complete work in the southern 28 counties so we can have resource data for this area available in June 1967. Field work for the rest of the State will be completed in the fall of 1967 and a comprehensive state statistical-analytical report will be prepared in 1968.

Additional funds have been provided by the Ohio Department of Natural Resources for an intensification of the field work in the southeastern 28-county area. This intensification will yield precise county data, and a unit report for this area will be prepared in 1967.

As a part of the resurvey and in cooperation with the Ohio Division of Forestry and Reclamation a survey of 1966 timber-production in the State will have begun in January 1967.

West Virginia Timber Production

The survey of current timber-products production in West Virginia is nearing completion. This study, which was funded through the Appalachian Development Act, was based on a canvass of all primary wood-using industries that utilized timber cut in West Virginia during 1965.

Analysis of the data from this canvass shows that in 1965 West Virginia produced nearly 500 million board feet of sawlogs; nearly 96 percent of this was hardwood and most of it oak. The production of veneer logs and bolts totaled more than 4½ million board feet. All of this material was hardwood. Cooperage log and bolt production amounted to nearly 4½ million board feet. Almost all of this material was white oak tight cooperage stock used in making barrels and kegs for the distilling industry. Pulpwood production totaled nearly 412,000 cords in 1965. Almost one-fourth of this total consisted of wood chips, produced primarily from sawmill slabs and edgings.

A report on this study will be available in 1967. In addition to data on production, the report will contain information about: (1) the timber cut/timber supply situation; (2) timber-based employment; and (3) other economic aspects of the timber-products industry of West Virginia.

PULPWOOD PRODUCTION IN THE NORTHEAST

To date three annual canvasses of pulpwood production in the Northeast have been completed. In January 1967 a fourth canvass got under way. A report for 1963 has been published and reports for 1964 and 1965 are being prepared for printing.

Addition of Ohio and Kentucky to the Station's territory in 1965 brings the total number of states included in these reports to 14. Production of all forms of pulpwood in the 14-state area totaled 4.6 million cords in 1964. By comparison, the 14-state area produced 5.1 million cords in 1965, a gain of 12 percent. The production of round pulpwood rose only slightly while the production of wood chips for pulpwood showed a substantial increase. Only two states—Massachusetts and New York—showed declines in chip production, and these decreases were only moderate. The largest gain in wood-chip production was in Pennsylvania.

FOREST RECREATION

OUR research program in forest recreation moved ahead this year in several ways. Recreation research formerly being conducted at Berea, Ky., and Warren, Pa., was relocated at the New York State College of Forestry at Syracuse University along with our cooperative recreation project already there. Our recreation research is concentrating on better means of utilizing both the public and private resource base to meet present and future demands for outdoor recreation. This objective can be realized if we find answers to three general questions:

- What are the forest recreation wants and needs of people in the Northeast now, and what will they be in the decades ahead?
- What recreation resources does the Northeast have available to fill those needs?
- What policies and programs are necessary to insure that the needs of the present and future are adequately and efficiently met?

Our research also has the objective to stimulate, encourage, and assist graduate students and faculty members throughout the Northeast in the biological, social-psychological, mensurational, economic, and multiple-use aspects of forest recreation research; and to conduct cooperative research on the basic relationships that may exist in outdoor recreation supply and demand.

Recreation on Privately Owned Land

Research into the opportunities for recreational development on small private woodlands continues as a major part of our work. We have just completed a survey of individuals and organizations that lease privately owned land for outdoor recreation in Indiana, Kentucky, and Ohio.

Responses from 43 of the 56 surveyed revealed the following information: (1) Forest-covered land comprises 54.6 percent of the total acreage leased in the three states. (2) Ponds and lakes are leased for an average of $4.87 per acre, forest-covered land at $0.48 per acre, and open land (old farms primarily) at $2.86 per acre. (3) Nearly half the leases are made because the land is favorably located and the rental rate is reasonable. (4) On land leased by organizations, fishing, hunting, picnicking, and target shooting comprise 56.5 percent of all activities provided, amounting to nearly 50,000 user-days annually. (5) On lands leased by individuals, fishing, hunting, and picnicking make up 57.9 percent of all activities provided, accounting for nearly 13,000 user-days each year. And (6) more than half (57.6 percent) the total acreage leased in the three states is used by hunting-shooting oriented organizations.

Success of Camping Enterprises

An analysis of 1963 attendance at 85 New Hampshire camping enterprises was published (our Research

Note NE-43) during the past year. Important to enterprise success were these factors: (1) number of years in business, (2) presence of a water attraction, (3) number of available campsites, (4) regional location, and (5) size of investment.

However, attendance, like income, is a poor measure of a young enterprise's eventual success. On the assumption that length and frequency of camping visits were reflections of a visitor's satisfaction with the enterprise, we also examined these factors at each of the 85 campgrounds. Again, the same five campground variables were found to exert significant influences over the length and frequency of visits. In addition, we found that camper-owned enterprises were significantly less successful in attracting long and frequent visits, apparently because most of these enterprises were small and were run on a part-time basis. The most influential variables affecting visit length were (1) the camper's equipment, and (2) his familiarity with the enterprise.

Campground Trampling Study

After 3 years of observation on a small number of campsites in the Allegheny National Forest, three observations are worth noting. First, an initial heavy loss of vegetation follows the onset of camping use and is strongly related to the amount of use received in the first year. Second, the plant species comprising the original ground cover undergo a gradual rearrangement in composition, and the more compaction and drought-resistant species become dominant. And third, this more tolerant ground cover temporarily increases its dominance while being subjected to continued heavy camper-use.

Panel Survey of New England Campers

The annual panel survey of camper's leisure behavior and investment, begun in 1964, continues to get a good response from participants. During the first year after the field interviews, the mail-survey responses were 94 percent for the 421 public campground visitors, and 93 percent for the 443 private campground visitors.

Analysis of the initial panel survey has developed a number of interesting and significant differences between the public and private sections of the panel. Most apparent is the high degree of mobility among a large segment of private campground visitors. And related to that mobility is the large dollar investment of many private campground visitors, with its implication of a semipermanent interest in camping, as well as a willingness of campers to pay a reasonable price for facilities and equipment that are attractive and convenient.

Recreation Survey Techniques

A study to compare camper response to different recreation-survey techniques —all using the same questionnaire— indicated that handout and mailed surveys (with three to four waves for nonrespondents) provided results that were comparable to personal-interview data for 75 to 87 percent of the question items. In the handout and mail surveys, attempts to contact nonrespondents beyond the use of three waves resulted in only a minor response. Conversely, when the same questionnaire was used in personal interviews, responses were obtained from practically 100 percent of the people in the initial sample.

Camper Classification Scheme

Based on significant differences among camping populations investigated in recreation surveys throughout

the Northeast, campers may be sorted into camping-experience classes as follows: (1) the neophyte, who camps for the first time; (2) the fledgling, who is gaining camping experience over a 2 to 5 year period; (3) the experienced camper, who has camped for 6 to 10 years; and (4) the veteran camper. Neophyte and fledgling campers seem to be found predominantly at campgrounds that are located near non-forest-oriented tourist attractions and the conveniences of a normal suburban environment.

Camping-Public Variability

Our recreation mensuration research has shown that Adirondack campers differ significantly between campgrounds and between months within the same campground, in terms of camper socio-economic characteristics, environmental preferences, reasons for camping, and attitudes about management. Thus, if data from a recreation survey are summarized across parks and/or months in which the data were gathered, as if to describe an "average" camping party within a given region, the results may be a nonexistent stereotype of a camping party. Furthermore, generalizations from survey results about an "average" camping party may create more managerial problems than the survey intended to solve.

WILDLIFE HABITAT

NEW wildlife - habitat - research funds were provided to the Station in July 1965. This project is located at our new laboratory in Morgantown, W. Va. At the close of the year two scientists were on the job and two more had been selected and will report for work shortly.

The new wildlife-habitat-research funds also enabled us to revise the research objectives of our wildlife-habitat-research project at Warren, Pa. The Warren project will now concentrate on developing methods of habitat management that will yield the amount, quality, and distribution of deer browse and other essential habitat components for the maximum deer population compatible with the production of timber products.

The research headquartered at Morgantown will seek to answer the major problems of habitat management for the optimum production of forest game that is compatible with other important uses of the Northeastern forests. Major emphasis will be on habitat management in the central Appalachians and the Appalachian outliers in Kentucky and Ohio.

Deer Habitat

The management of forest habitat for white-tailed deer is of high priority in the Northeast. A problem has developed over many years in all the big deer-producing states, as the result of an unplanned and unregulated change in deer habitat. In some states, good deer habitat has declined in recent years and is now too poor to maintain the desired population of deer. In other states, deer habitat changes er-

ratically: it may become too poor in some sections of a state and very good in other sections.

And in all these states management for deer habitat is rather poorly integrated with other important and growing demands on the forest resource, including hunting of other forest game species. One result is that the traditional and once dependable process of satisfying the public demand for forest game by regulating the game harvest is becoming increasingly difficult to sustain in the absence of any continuous habitat-management program.

In our wildlife-habitat-research program we recognized early that improvements in deer-habitat management generally resulted in significant improvements in the habitat of other forest game species. Deer-habitat management has been coordinated with timber-management activities, and especially with cutting practices. Thus our habitat-research program has emphasized the study of problems in habitat-timber relations, and increasingly in the last 2 years the problems of coordinating timber-management and deer-habitat-management objectives.

Much of our research is concerned with deer habitat-timber relations. This work for the most part directly or indirectly involves the yield, utilization, or quality of deer browse produced under even-age systems of timber management in northern hardwoods. Nearly all of this research is being conducted in cooperation with the Fish and Wildlife Service, the Pennsylvania Game Commission, or The Pennsylvania State University.

Deer Browse and Even-Aged Management

The potential for coordinating deer habitat and timber management has improved with the recent advent of even-age management systems in northern hardwood stands. The general impact of these systems on deer habitat is the development, under unit-area management, of plant associations in different stand-sizes, each of which is within the daily range of movement of a single deer. The result of this is that the production of deer browse has a wide range of abundance in discrete identifiable levels by stand-sizes, and in which the largest part of the browse that is produced is open-grown in the patches clearcut for the natural regeneration of timber stands.

The first few years after clearcutting are the most critical in the cycle of production of both timber and deer habitat. Our research indicates that the density, composition, quality, and form of both the new timber stand and the deer browse are determined equally during this critical period; and also, that interactions between site conditions and the level of deer browsing during the same period have the greatest influence in determining timber and browse values in the forest stands that follow. Thus a given level of deer browsing on moderate to poor sites may further reduce future yields of timber and browse, while on the best sites it may have only a minor effect that can be beneficial if, for example, it holds back the growth of stump sprouts.

Browse Yield After Clipping Seedling Terminal Shoots

The most desirable commercial species among northern hardwoods generally are also those that deer prefer for browse. Simulated browsing, by clipping terminal shoots of seedlings of four of these species for 5 years, showed that the most valuable species among those tested — black cherry — was least able to maintain good form. All species had a high survival rate; but whether the poor form that clipping produced in all these species will be corrected in future years remains to be determined.

Medium intensity of clipping gener-

ally produced the best yields of browse. As expected, height growth was reduced roughly in proportion to intensity of clipping. It may be assumed that a critical point of browsing is reached on a management unit when some as yet to be determined proportion of seedlings are browsed at a given level of intensity. And because deer show a preference among browse species, the commercial species most vulnerable to the effects of browsing should be selected for use as a guide to determine the permissible browsing level in a regeneration stand.

Do Deer Maintain Open Types of Forest?

The impact of deer browsing in a savanna type of forest in northern hardwoods is being studied in cooperation with the Fish and Wildlife Service. Permanent or semi-permanent openings commonly occur in this cover type, but the ecological factors responsible for their persistence have not been adequately defined.

After 2 years of protecting plots from deer browsing, evidence suggests that some openings may be held in the grass-herbaceous stage for long periods by heavy deer browsing. There was no lack of shrub and tree germinates and small seedlings in the sample plots that were open to deer browsing, but grazing by deer (and possibly by other animals) apparently is preventing the height growth of woody vegetation and the subsequent formation of a hardwood overstory.

Because openings are important not only in the habitat requirements of deer but also of several other forest game species, it is tempting to hypothesize that the maintenance of open areas by deer is both a survival mechanism and an important factor in determining the association of deer in a natural community with other game species that also require the open type.

If such is the case, the number, size, and distribution of such openings becomes a function of the size of the deer population. It seems unlikely that such a straight-line relationship exists, but instead that there is an interaction of browsing with other factors that brings about the desired effect.

Deer Preferences and Browse Nutrition

The preferential use of openings by deer is well known. Partly this is a preference for open-grown forage. Deer further discriminate in browsing by generally eating only the tips of the terminal shoots of woody plants. This preference may be related to differences in the nutritional content of the different parts of a plant.

To find an explanation for the browsing habits of deer in relation to the nutritional content of seedlings and sprouts of two species we are conducting research in cooperation with the Department of Animal Industries and Nutrition of The Pennsylvania State University. Preliminary results of analysis for crude protein content showed that in black cherry seedlings there is a gradient in the level of this element, the highest level occurring in the terminal bud, and lower levels of protein in each successive section of the terminal shoot. The lowest level was found in the wood of the previous year's growth. The buds of dormant seedlings contained 23 percent crude protein, a level considerably above the 13 to 16 percent of protein tentatively recommended for the growth and development of male fawn deer observed in pen experiments.

This research is being expanded to include biological tests with penned deer fed natural browse of a given nutritional content. Relationships in nutritive yields and digestibility of browse between domestic ruminants and deer will be studied. The role of dietary needs as opposed to the use of single food items will also be explored.

INSECTS & DISEASES

WHEN the Forest Insect and Disease Laboratory at Delaware, Ohio, was transferred to the Northeastern Station in the recent reorganization, our staff in insect and disease research more than doubled. Including projects at our laboratory at West Haven, Conn., we now have six insect projects and three disease projects—one of the largest regional research programs of its kind in the Nation.

Some New Developments

- The pest-control unit of State & Private Forestry has established a zone headquarters for entomologists and pathologists at our laboratory at Delaware, Ohio. The present staff of five is headquartered in temporary quarters, which contain both office and laboratory space. When our laboratory expansion, now being planned, is completed, the zone office staff will be located in main buildings. The transfer of this pest-control unit to Delaware will achieve much closer working relations between research and S&PF programs and will accelerate on-the-ground application of research results.

- New cooperative aid studies were negotiated in 1966 with the following universities: (1) The Pennsylvania Department of Entomology, "A study of development and behavior of fall cankerworm larvae and adults"; (2) The Pennsylvania State University Department of Mathematics, "Statistical measures of aggregation in forest insect populations"; (3) Yale University School of Forestry, "Study of certain analytical techniques applicable to the measurements of forest insect populations and their impacts on the forest ecosystem"; and (4) West Virginia University Department of Plant Pathology, Bacteriology, and Entomology, "Oak wilt study." This last study will deal with the relative values of spermatization and serological techniques for detecting varying oak wilt fungus spore loads carried by nitidulid and bark beetles under different conditions.

- One new project, "Impact of insects on northeastern forests," was formally approved and established at West Haven. This project, under the direction of Dr. W. E. Waters, is designed to evaluate and predict the impact of destructive insects on northeastern forests with a view to providing forest managers with guidelines for controlling these pests. It is staffed with five scientists.

- Another project, "Biology and control of insect pests of shade trees in the northeastern United States," headquartered at Delaware, was completely revised to emphasize the growing need for controlling insect pests that damage or destroy shade trees in cities, parks, and along highways.

- One project at West Haven ,"Chemical control of forest insects in the Northeast," has been terminated. The responsibility for research for-

merly included in this project has been transferred to the shade tree insect project described above.

- Construction of the new Forest Insect and Disease Laboratory at Hamden, Conn., is progressing on schedule. This building will provide modern office and laboratory facilities for 15 to 18 scientists and an equal number of technicians and other supporting personnel. The laboratory site covers 10 acres, including a scenic pond. Our staff at the West Haven laboratory will transfer to the new laboratory on or about July 1, 1967.

FOREST INSECT & DISEASE LABORATORY

West Haven, Conn.

Insect Biology

White-pine weevils (*Pissodes strobi* (Peck), *P. approximatus* Hopkins, and *P. nemorensis* Germar) are considered to be valid species. They can be distinguished from one another by differences in karyotype, host plant, breeding site, and geographical distribution. Although the species differ in these respects, the external morphology of the individuals comprising these populations is so similar that they cannot be identified as belonging to one species or another on appearance alone. This places a severe handicap on field studies of behavior or population dynamics, since the identity of the individual is imperative and the biological information required for the identification is not known.

Biometric techniques have been developed that permit prediction of the likelihood of an individual thing being in a particular class of things, on the basis of many subtle but measurable differences among the individuals in a defined population. We have used one such technique—discriminant analysis—to measure the similarity of individuals within the three weevil populations.

Eighteen morphological characteristics were measured on individuals of each species. The identity of these individuals was determined on the basis of biological information. Nine of the characters measured proved significant for discrimination of the species. When these predictor variables were used to classify independent samples of the three species, 95 percent of the *strobi* population were correctly placed; 5 percent were misclassified as *P. approximatus*. Of the *approximatus* sample, 66 percent were correctly identified; but of the 34 percent misclassified, only 5 percent were called *strobi*. *P. nemorensis* individuals were correctly identified 88 percent of the time; 2 percent were misidentified as *strobi* and 10 percent as *approximatus*.

Since *P. strobi* is the species of most interest, the use of discriminant analysis provides a relatively reliable and simple method of identifying individuals of this species on the basis of morphological characters alone.

Our studies of sparse but stable gypsy moth populations, which were commenced in 1965, were continued in 1966. We have now accumulated population data from a larger number of 0.01-acre plots located in the Nipmuck State Forest in northeastern Connecticut and the Brimfield State Forest in an adjacent part of Massachusetts.

We knew from our 1965 work that the larger caterpillars tended to stay in bark flaps on dead limbs of the host trees during daylight hours if such flaps were available. If bark flap niches were not present, nearly all of the insects moved downward to the litter around the base of the tree. The rate of insect survival from day to day was much higher among the insects on the trees than among those in the litter. Vertebrate predators, notably white-footed mice, consumed nearly all of the insects in the litter.

Briefly, these results indicate that the probability of a gypsy moth surviving from egg to adult was closely related to the number of bark flaps per unit area under the conditions that we have studied. Several other facts were uncovered. First, male insects made much greater use of bark flaps as pupation locations than females (47.5 percent vs. 24.1 percent). Second, the probability of pupal survival was higher in bark flaps than in other locations. Third, the survival rate of female pupae was lower than that of the males, and this differential was determined primarily by a higher mortality among the female pupae due to vertebrate predators.

All together, our results to date confirm the premise that the natural maintenance of a sparse gypsy moth population at an innocuous level is determined largely through a series of interactions between niche availability, the behavior of the larger caterpillars and pupae, and the numbers and behavior of the white-footed mouse and other vertebrate predators.

Biotic Control

The main emphasis of this project has been more diversified this year than in previous ones. Work has concentrated on the development of microbial agents for insect control; forest insect tissue culture for basic virology studies; investigations of the role of non-spore-forming bacteria and anaerobes in disease in natural populations; and techniques for producing and separating toxic components of the bacterial pathogen *Bacillus thuringiensis (Bt)* and related organisms.

Our research staff participated in an international effort to test commercial *Bt* preparations in order to arrive at an acceptable international standard for reference purposes. Materials tested were prepared by the Bioferm Division of International Minerals Corp., Nutrilite Corp., and the Pasteur Institute. Our tests with *Bt* were conducted against the gypsy moth and fall cankerworm. Results of these tests were presented and discussed at the International Colloquium on Insect Pathology in Wageningen, The Netherlands. This cooperative effort resulted in the adoption of the French (Pasteur Institute) standard as the international standard. The need for standardized techniques and animals for bioassay was sharply pointed up and the insufficiency of the viable spore counts was very obvious from the data presented.

A pilot trial of two commercial *Bt* products against the gypsy moth was again conducted in cooperation with the Connecticut Park and Forest Commission, the New York State Museum and Science Service, and the New York Conservation Department. All applications were made at the same rate (2 gal./acre), by light fixed-wing aircraft.

In Connecticut, eight spray blocks received either a single or double treatment of Thuricide 90TS, extended activity (2 pints of Thuricide, 6 fluid ounces of Pinolene 1674 diluted to 2 gallons of finished spray). Four plots received a single treatment when oak expansion was nearly full, and the other four plots received a second treatment 10 days later.

The control effect in Connecticut was obscured because the gypsy moth population suffered a general collapse. The effect of the double treatment was very noticeable at first and gave slightly higher egg-mass reduction than either the single treatment or the untreated areas. The Pinolene 1674 gave very good sticking and weathering characteristics to the spray. Active spray material was recovered from treated foliage 4 weeks after application.

In New York, eight spray blocks received a single treatment of either Thuricide (same formulation as in Connecticut) or 1 pound of Biotrol 25B process 183 plus 6 fluid ounces of Pinolene 1674 in 2 gallons of water.

The insect population in New York

also collapsed; and this, together with considerable shower activity during spray application, made evaluation very difficult. In fact the untreated areas showed greater egg-mass reduction than the treatments with either materials.

Nevertheless two concrete accomplishments can be claimed: (1) the addition of a compatible sticker-anti-evaporant, such as Pinolene 1674, extended the activity of the material far longer than had previously been observed; and (2) the better immediate effectiveness of the double treatment over the single treatment indicates that multiple applications of *Bt* material may be required for acceptable control in forest spraying.

The culture of insect tissues in semi-artificial media has not progressed as far as mammalian cell culture. In rare cases where insect cells have been successfully cultured and proliferated, the need for insect hemolymph has been strongly indicated. We have been working on a medium containing hemolymph from other-than-insect arthropod sources and have successfully cultured gypsy moth tissues with some cell proliferation in this medium. Culture "turn-over" has not yet been achieved.

The continuing search for micro-organisms responsible for natural mortality in gypsy moth populations has indicated that members of the bacterial genera *Bacillus, Proteus, Streptococcus,* and *Pseudomonas* occur regularly in dead insects. The role of these organisms in the natural population is now under study. Preliminary studies conducted this year indicate that anaerobic bacteria do not play a significant role in natural mortality of the gypsy moth.

In our studies of the crystal toxin of *Bt,* the need for a very clean spore-crystal preparation for physical separation of the crystal was obvious. An intensive effort was directed toward development of a medium that would produce an adequate supply of this starting material efficiently, quickly, and cleanly. A modification of the G-minerals medium of Halvorson has provided us with this necessary clean spore-crystal material. Physical separation of the spores and crystals is now under way.

In light of the recent Forest Service moratorium on the use of insect viruses for forest insect control, an intensive comprehensive study has been drawn up with entomologists of the Northeastern Area S&PF. This cooperative study is designed to provide the necessary information on *N. sertifer* virus and its effects on the host insect and other animal life for clearance and registration by Federal Defense Agency and United States Department of Agriculture.

This virus has been successfully used in the past in the United States and Canada and has demonstrated effective control of the sawfly. Because of this demonstrated effectiveness and the damage caused by the sawfly, this virus-insect combination was selected for the first Research—I & DC effort to provide sufficient information for registration and clearance of the virus for *N. sertifer* control.

Insect Impact

Study of the impact of insects on northeastern forests was formally established as a research project of the Station this year, though recognition has been given it as a discrete study area since 1962. The output of forest insect research — fundamental information about the biologies of destructive pests, their interrelations with individual host trees and forest-stand environments, and direct and indirect means of regulating their population densities—must be made relevant and useful to all levels and functions of management. This is the aim of the project.

Progress was made in the development of both measurement and ana-

lytical techniques. For example, radiographic equipment was purchased and techniques were developed for obtaining a quantitative record of when and how mortality of the white-pine weevil occurs during the critical period in host tree leaders. A GE Model LC-90 portable X-ray unit with the CSI-25 tubehead was chosen for its compactness. Various types, sizes, and shapes of film were tried; and Kodak type M (industrial) 3½ x 17 inches proved most efficient for shots of whole leaders or large segments of them. The best series of photos were obtained with an exposure of 200 milliamp seconds at 21 inches with a kvp of about 22. Weevil eggs, larvae, pupae, and adults along with parasites, predators, and casual visitors to the weevil galleries showed unmistakably on these photos.

We began a cooperative study with the Department of Mathematics of The Pennsylvania State University, to probe more deeply into the form and interpretation of quantitative indices of spatial distributions among forest insects. Spatial pattern has ecological significance as well as statistical relevance, and therefore valid measures of it must be recognized and/or incorporated in the analysis of insect population data.

Field data on the red-pine scale obtained from five study areas in southeastern Connecticut over a 6-year period (through a cooperative aid study with the Bartlett Tree Research Laboratory) were compiled and reduced for analysis of sampling variation. Specific branch sections of designated sample trees were collected at successive times to permit counts of the insect in seven stages in each of the two generations each year.

In brief, it was shown that there was a significant difference in mean counts according to plot location, branches within trees (inter-tree variation within plots was not significant), branch node vs. internode sections, insect stage, and generation. Also, the counts on the most distal branch segment were consistently highest. Thus observations for the purpose of detecting the scale could be made on this segment alone (and perhaps the next most distal segment for greater assurance). This and other pertinent recommendations were given to the Forest Protection Branch of Northeastern Area S&PF and to state cooperators for conduct of the current survey for red-pine scale in Connecticut, New York, and New Jersey.

Ways of developing life tables of forest stands were studied. The full accounting of tree mortality and other loss, *by cause,* over the time-span of a tree crop is a basic requisite for thorough analysis of forest productivity. Productivity is always a net value, so it is a function of both the building-up elements and the destructive elements. Maximal (or optimal) productivity and value can be achieved only if insect impact and other catabolistic effects are minimized.

We now lack the quantitative data on insect-caused losses that are necessary for life-table compilation, but the critical events in the life history of a forest stand can be organized in this format—and at least we can discern the age interval in which losses most strongly affecting final yield occur. Then attention can be focused on this period of tree growth and stand development. A logical sequence of analytical steps has been proposed to unravel the biological and economic complexities of forest stands. Eastern white pine serves as the first species of interest.

Another contribution to analytical methodology applicable to life-table data was made when we showed how joint variation among the so-called independent variables may be highly significant in determining variation in the dependent variable (survival rate, say); and if variance, in the statistical sense, is taken to be the measure of variation in both sorts of variables, then joint variation among the independent variables is expressed by the respective

covariance terms and analyzed accordingly. Application of this technique to the analysis of gypsy moth life-table data has proved very useful.

New England and New York Tree Diseases

Our research in this project is centered primarily on the dieback and decline diseases, and on discolorations and decays. The latter work is being done at Durham, N. H.

A study to determine the impact of basal canker on white pine on stand structure was continued this year. Low-level aerial infrared-color and true-color photographs were made of selected plots in affected stands, and these photos are being analyzed. Data acquired directly from films and data obtained on the ground are being compared for accuracy in classifying tree conditions and measuring tree distributions.

Aerial photography also was tried, in a preliminary trial with beech bark disease, as a possible aid in our studies of diebacks and declines. Our first photographs lacked contrast, but the results were promising enough to warrant further trials. This study was prompted by our need to map and measure the development of dieback and decline diseases at frequent intervals over relatively large areas in order to obtain information about rates and patterns of disease development. Such information, now unavailable for diebacks and declines, is necessary for our planned investigations to quantitatively describe the epidemiology of these forest tree diseases.

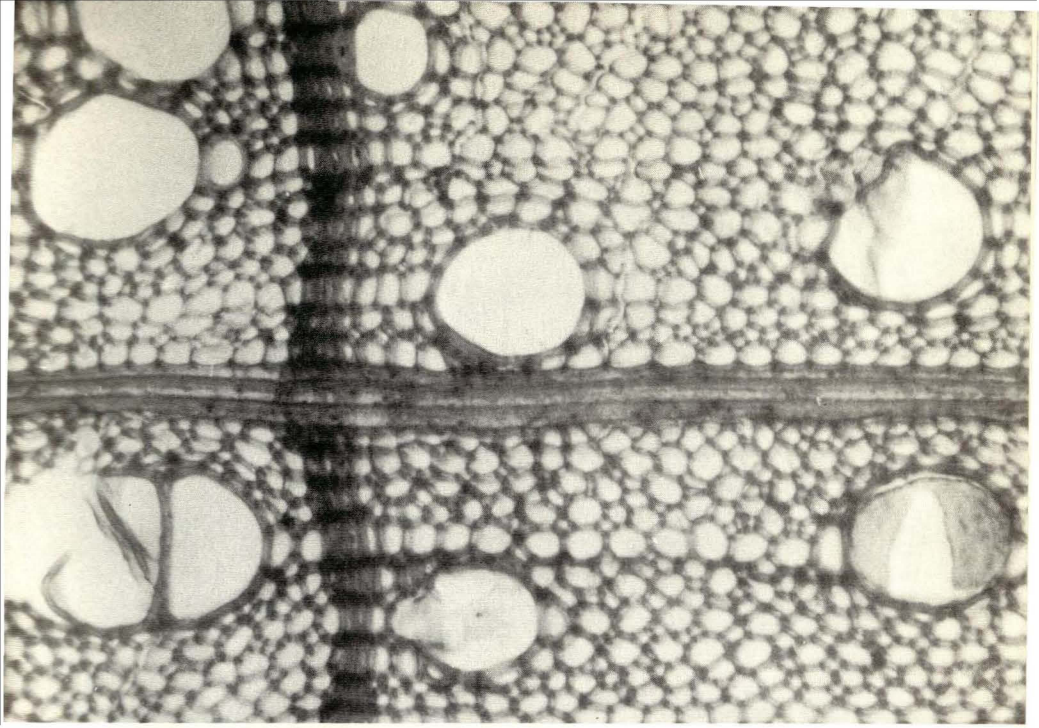
Our present studies in epidemiology, therefore, are utilizing data now available for other types of tree diseases. For example, with data from the cooperative oak wilt pest control appraisal plots, we are attempting to construct mathematical models of disease increase. Data from 1958-63 are being analyzed with respect to existing models of plant and animal diseases. Ultimately the dieback and decline diseases will be examined in this way. We anticipate that this approach will lead to a better understanding of the initiation and subsequent spread or intensification of forest tree diseases, thereby suggesting bases for evaluating control procedures and areas for further study.

Other aspects of diebacks and declines are also being studied. One of these is the description and definition of the physiological responses of trees to various stress phenomena. Research in this area is being pursued in studies of: (1) drought resistance in roots of red oak, sugar maple, and white ash; and (2) effects of defoliation on root food reserves and on subsequent crown decline of sugar maple.

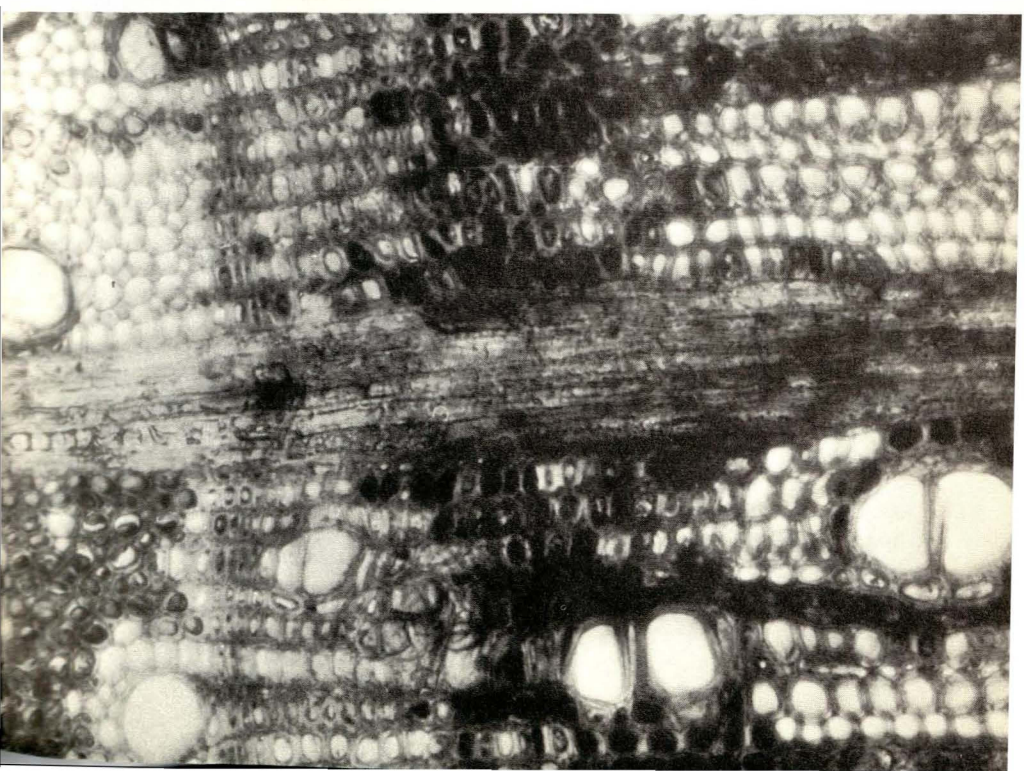
Results of the first study indicated that resistance to desiccation of root tissues was not unusually high—approximating that for leaves. Though no species differences appeared in terms of cellular desiccation resistance, there were differences in the rate of water loss by evaporation from whole root segments. The bark of sugar maple roots was more permeable to water than was the bark of oak or ash roots.

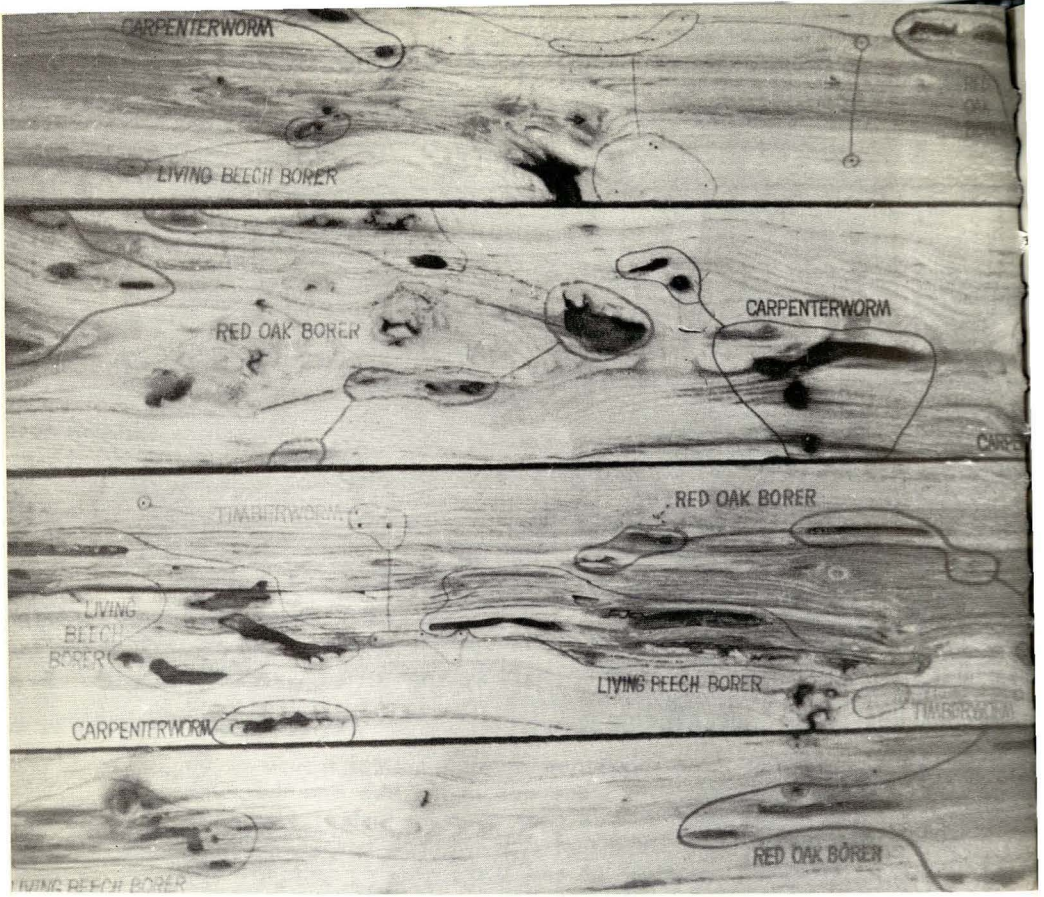
In the second study, the effect of defoliation on root food reserves was profound. In the first year of this 3-year experiment, food reserves were reduced markedly after one defoliation and even more after two defoliations the same season.

Studies of discolorations and decays continued along the same lines as in the past, but with emphasis on the nature of and reasons for the successions of organisms in wood. In one study, isolations were made from the discolored and decayed tissues in trees inoculated with a decay fungus 5 years ago. The inoculum fungi were not recovered from all of the trees; and those that were recovered were restricted to those tissues present when the tree was inoculated. The tissues that did yield them were surrounded by tissues that



Radial sections of Acer saccharum showing normal tissues at an annual growth ring (above) on one side of the tree and the same growth ring on the opposite side near a wound (below). Growth is from left to right. The dark line of cells (vertical) perpendicular to the ray (horizontal) formed at the end of the growing season. Many changes, both anatomical and physiological, are initiated by wounds.





Insect damage to lumber found in a mill study.

yielded bacteria and non-decay fungi. The consistent relationships in time and place of these organisms, found here and in previous studies, indicated that only those tissues infected first by bacteria and non-decay fungi were successfully infected later by decay fungi.

Several studies are under way to clarify these successional patterns. Early results of an investigation of the tissue changes that occur after wounding suggest that anatomical changes may account in large part for the restrictions of discolorations and decays to tissues present when the trees were wounded. The most significant changes occurred in the ray cells. In discolored tissues, altered cells contained many different types of materials, indicating that discolorations probably result from many different processes.

Investigations of the bacteria associated with discolorations continued in studies designed to clarify the roles of these organisms in the discoloration-decay processes. Representative isolates were tested for thiamin production. All pseudomonads isolated from northern hardwoods produced this vitamin, which is essential for growth of many decay fungi.

FOREST INSECT & DISEASE LABORATORY

Delaware, Ohio

Silvicultural Control

The major goal of our research in this project is to reduce insect losses to upland hardwoods by silvicultural methods. Our studies are directed toward those insects responsible for quality decline and understocking in hardwoods. Our principal targets are borers, aphids, weevils, scales, and seed-inhabiting species.

Loggers in upland hardwood forests have long been aware of the losses associated with insect-caused defects. This impacts has been felt at the mill as well as in the forest. Heavily damaged trees have been accumulating for years as culls; and damaged sawlogs of black, scarlet, and red oaks continue to be harvested from the poorer sites.

Careful examinations of standing trees, sawlogs, and lumber have been made throughout eastern Kentucky. These observations showed that the most extensive damage was caused by the carpenterworm and the red oak borer. They also revealed that oaks showing extensive heartwood decay are likely to be heavily infested by wood borers. The intimacy of this relationship between decay organisms and wood borers remains a mystery.

We found that the carpenterworm needs wounds to gain access to the inner wood. The red oak borer conveniently provides such wounds through its normal activity. The red oak borer lays its eggs in bark crevices or beneath lichen patches. The young larvae then bore directly into the inner bark phloem, thus providing access roots for the carpenterworm and disease organisms.

We have found that the proper timing of stand improvement and timber harvest will produce a high rate of red oak borer mortality. This work was conducted on a limited scale, but it appears that a silvicultural control for the red oak borer (and thus the carpenterworm) is possible.

We are now planning to try this procedure on a larger scale and at different locations within the upland oak type forest.

To determine the impact of insects on natural regeneration of oaks, we are investigating the insect pests of acorns, particularly acorn weevils.

Our first step in this has been to develop methods for identifying larval forms of weevils belonging to the genera *Curculio* and *Conotrachelus*. This toxonomic information was essential because, until this work was completed, it was impossible to separate the species of weevils except in the pupal and adult stages. These investigations have now been expanded to

Adult red oak borer.

Curculio larval "trails" in acorns.

include all the acorn-inhabiting weevils of North America. A revision of the genus *Curculio* in North America now in preparation will provide additional information about host-tree species and geographic distribution of the pest insects.

We can now associate larval feeding activity with the responsible adult weevil. Thus we can estimate the impact of various species of weevils on an acorn crop in any given year or location. We have determined that certain species of weevils are very host-specific, while certain other species feed on a number of different oak species.

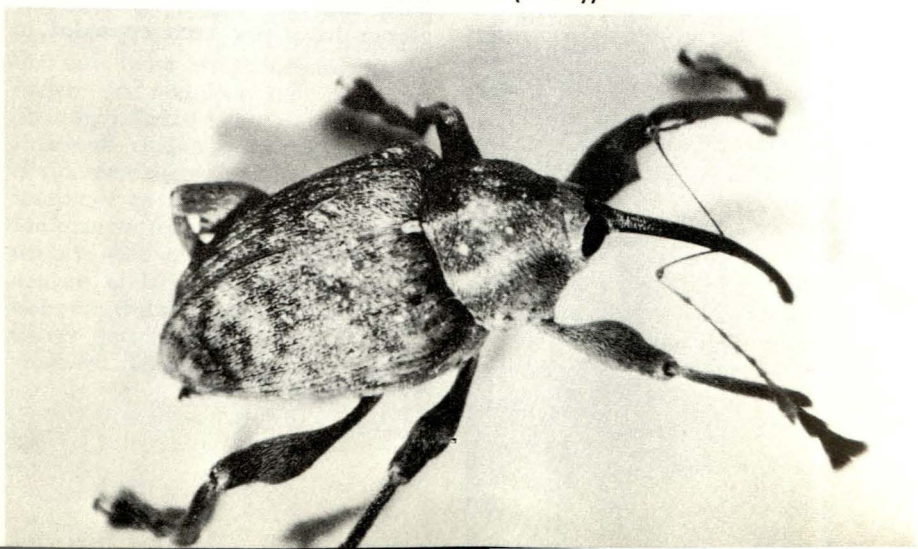
Extensive weevil feeding will obviously prevent sprouting, but the extent of insect feeding necessary to limit sprouting or reduce seedling survival is still unknown. Hence an informal cooperative study with the Ohio Division of Forestry has been initiated to determine just how much and what kinds of weevil feeding affects sprouting.

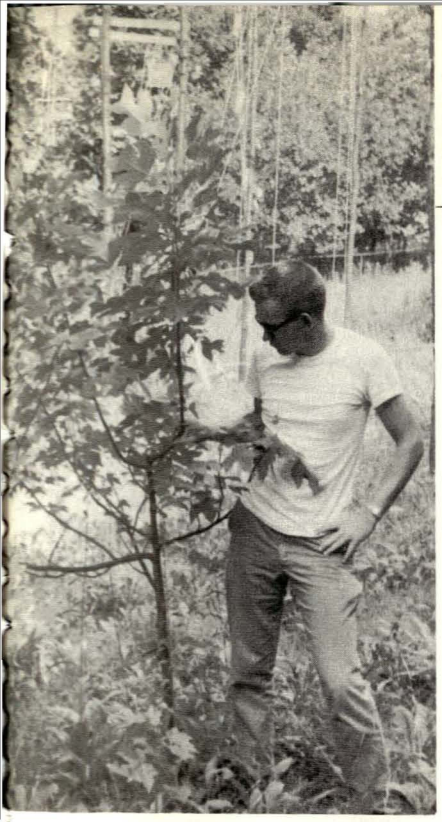
A number of insects influence the species composition, stocking level, and individual tree form in our mixed hardwood stands. An example of this type of insect is the tuliptree scale, which is found throughout the natural range of yellow-poplar.

The tuliptree scale injures the host tree by inserting its beak into yellow-poplar branches less than 3 inches in diameter. The insect then withdraws tree sap and excretes the unused portion, along with its body waste, in a liquid form called honeydew.

Our research, through carbon analysis of honeydew, has demonstrated that 1,000 scales will excrete about 20 grams of carbon in a 24-hour period. The infested yellow-poplars respond to

Curculio iowensis (Casey).





Permanent crook resulting from scale damage.

this energy drain, along with associated mechanical injury, either by dying or by exhibiting poor growth and vigor. When 6-inch trees are killed, multiple sprouting is the rule. Lighter scale attack and correspondingly limited infestation will cause branch dieback. This in turn results in trees having distorted stems and double tops.

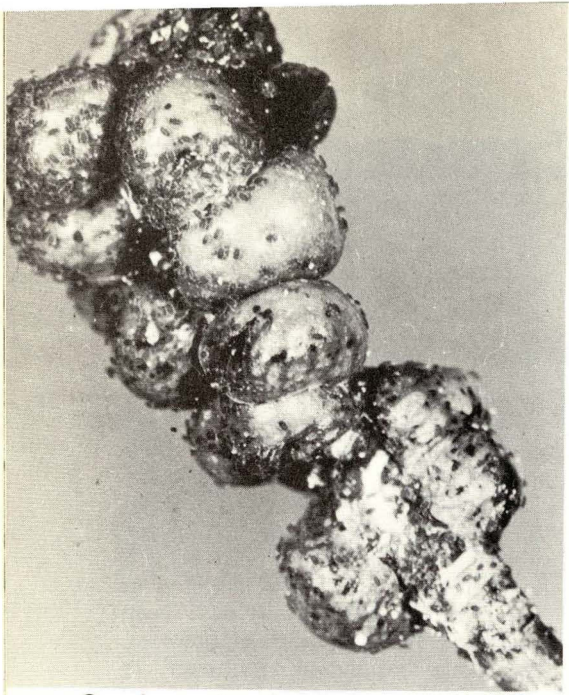
The tuliptree scale is sometimes kept at non-damaging levels by its natural enemies, including parasites, lady beetle predators, and a moth predator.

Our research has demonstrated that the normal effects of parasites and predators on this scale are severely reduced by ants gathering honeydew. Apparently the ants do not seek out parasites and predators but merely disturb their egg-laying and feeding activity. Further research on the tuliptree scale revealed that the crawlers are carried from tree to tree by the wind and have been recovered 200 feet from an infested tree.

This ecological research suggests two means of controlling the tuliptree scale: (1) by screening the crawlers out of the wind with species of trees that will not support the scale; and (2) by disturbing the ant/scale relationship. A number of plantings in which yellow-poplar has been planted in alternate rows with such species as red pine and black locust have been examined. In such plantings, however, the scale infestation continues to progress down the rows of yellow-poplar. We are now experimenting with the alternate planting of red pine and yellow-poplar within rows.

In laboratory experiments we have found that the ant species responsible for parasite and predator decline is very responsive to sunlight and soil temperatures. We are now seeking ways to alter the soil temperature in field plots to control ant movement and distribution.

Ants gathering scale honeydew.



Crawlers on female tuliptree scales.

Shade Tree Insects

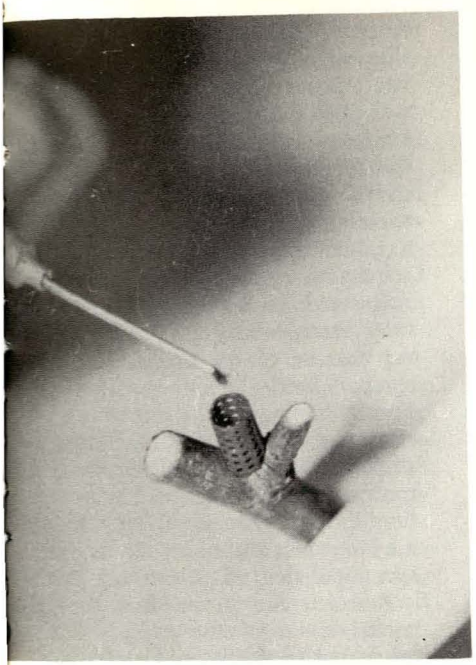
The objectives of this research are to improve old and develop new methods and materials for the control of insect pests of shade trees based on sound physiological and toxicological research. At present our efforts are concentrated on four primary areas of research: (1) toxicological studies to evaluate certain systemic organophosphate insecticides for control of shade-tree insects; (2) studies to isolate host attractants, arrestants, and feeding stimulants and to evaluate these chemicals as to their effect on insect behavior; (3) studies on indigenous and imported parasites of the smaller European elm bark beetle; and (4) studies to determine the nutritional requirements of shade-tree insects as a basis for rearing standardized colonies of insects on natural and artificial diets.

A new technique was developed for bioassaying American elm twigs for systemic insecticide residues. The conventional assay method for residual surface sprays (DDT and methoxychlor) is not applicable when organophosphate insecticides (for example, Bidrin and Thimet) are employed because of the more rapid metabolism of these insecticides in plant tissue as compared with those of residual insecticides.

In this new technique, direct results are obtained by using the smaller European elm bark beetle, the primary vector of the Dutch elm disease, as the assay agent. Elm material is collected in the field and immediately flash frozen in liquid nitrogen to prevent further metabolism of the insecticides. The beetles are confined on each thawed sample in a small perforated brass cylinder fitted in the twig crotch for 24 hours at 30°C. and 80 percent relative humidity. Results are measured in terms of whether or not the treatment prevents the beetles from penetrating through the phloem into the xylem tissue, where disease inoculation occurs.

A study was conducted to determine if organophosphate insecticides undergo degradation under cold storage conditions (—10°C.). Bioassay material

Quick-freezing elm crotches in liquid nitrogen.



Caging Scolytus multistriatus, the smaller elm bark beetle, on elm crotch.

(American elm twig crotches) was taken from pairs of treated and check trees, frozen in liquid nitrogen and transferred to —10°C. storage. Bioassays were run, using the smaller elm bark beetle on fresh crotches, and the results were compared with bioassays run on stored crotches held from 1 day to 6 months. A linear regression analysis indicates no significant pesticide degradation within American elm crotches under cold-storage conditions. However, a T-test analysis reveals a significant difference between bioassays run on fresh and frozen crotch samples, indicating an effect attributable to quick freezing.

Research during 1966 also involved preparation for a 1967 field study to determine the relative effectiveness of four organophosphate insecticides for control of various maple shade tree aphids. The maximum allowable doses for these compounds based on tree phytotoxicity, have been determined and will be used to compute dosages in future research. Leaves from 100 treated silver maple trees were collected at four time intervals, quick frozen in a CO_2 ice chest and stored at —10°C., for later bioassay improvement techniques, using the fruit fly, *Drosophila melanogaster* (Oregon-R strain), as an assay organism.

In an attempt to define the host selection behavior of the smaller European elm bark beetle and the mimosa webworm, research has continued on the isolation of host constituents that act as feeding stimulants. Pharmacognosists in the Ohio State University Department of Pharmacy, acting under a grant from the Forest Service, have prepared extracts of elm bark and submitted their extracts for bioassay to determine if they contain elm bark beetle feeding stimulants. A methonal fraction, which shows consistent feeding stimulant activity when incorporated in a synthetic agar-cellulose pow-

Adult elm bark beetle feeding in crotch of synthetic "twig" containing agar, cellulose powder, water, and an elm bark extract.

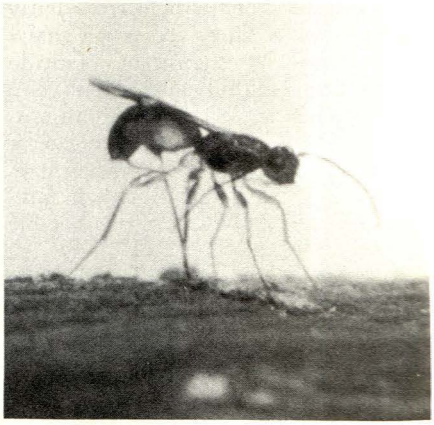
der "twig" is being column-chromatographed in an attempt to isolate the stimulatory chemical.

In a similar study, we have shown that mimosa webworm larvae are stimulated to feed on an agar-cellulose powder diet containing extracts of honey locust leaf powder. A fecal-pellet count was used as an indication of stimulatory activity. An active water soluble fraction was precipitated with lead, and the supernatant from this precipitation was then column-chromatographed. Thin-layer chromatography of the active column fractions demonstrated the presence of sucrose and fructose. A chloroform soluble fraction, which is inactive by itself, stimulates larval feeding in combination with low concentrations of the stimulatory sugar sucrose. The activity of this combination is greater than that of sucrose alone. Studies are in progress to isolate this chloroform-soluble material, which apparently synergizes the activity of sucrose.

Research on the braconid, *Dendrosoter protuberans* (Nees) Wesm., larval parasite of the smaller European elm bark beetle, recently imported from France, has indicated that it has a good chance of becoming established as an addition to the already present spectrum of biological agents that act continuously to reduce in varying degrees the biotic potential of the North American populations of the elm bark beetle.

Research has shown that the imported strain of the parasite which originated from the milder climate of Southern France can overwinter in our region, but the ability of the parasites to overwinter under extremely severe conditions needs to be determined.

Parasite-dispersal studies were undertaken, using plots of systematically ar-



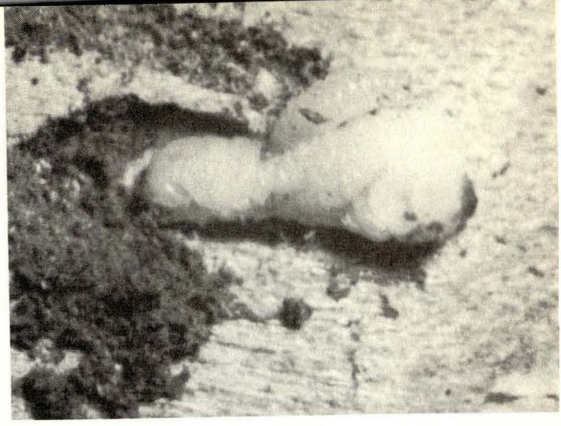
Dendrosoter protuberans ovipositing in elm log.

ranged trap logs infested with elm bark beetles and releasing parasites at the center of each plot. Parasites were released as free adults or allowed to emerge from bolts previously infested in the rearing room. This gave an indication of the dispersal-distance-dilution factor of the numbers of the parasites released. Future plans are for integrating the parasite into the natural field cycle of the smaller European elm bark beetle with its indigenous parasites and predators in several geographic areas.

A method has been developed for year-around rearing of the mimosa webworm. Field-collected larvae are reared to the cocoon stage on a semi-artificial diet in the summer months. In the fall, the cocoon are transferred to the greenhouse in small cages containing honey locust seedlings, and adult moths begin to emerge in early winter. Mating and oviposition are very slow at first, but accelerate markedly after the appearance of the first few larvae. This acceleration appears to be stimulated by the feeding activity and webbing of young larvae.

The seedling trees infested with small larvae are periodically removed from the cage and placed around larger 6- to 8-foot honey locust trees, and the larvae are reared to their last instar. These larvae are used in laboratory studies or are reared to pupae on the artificial diet. Several generations can be reared per year in this manner. Artificial diets have not yet permitted complete development of the larval stage.

A very successful technique and artificial medium for rearing larvae of the smaller European elm bark beetle have been developed. The completely synthetic medium consists of cellulose powder, agar, water, and various nutrients. Excess water in the medium is removed with a laboratory press. Newly hatched bark beetle larvae are placed in small holes in the medium and the medium is sealed between plate glass.



Larva of Deidrosoter protuberans attached to larger elm bark beetle larva.

Survival to the adult stage has averaged 80 percent by this method. No oviposition has occurred in this particular diet, but oviposition has been obtained in altered phloem diets with limited success.

Biological Control and Insect Vectors

One theoretical way to control forest insects is to develop pest-resistant strains of trees that are not acceptable to the insects as food. Experiments to determine the resistance of selected tree strains require these conditions: that the trees are of a species that is chronically attacked by the insect; and that both the trees and the insects are present in enough numbers to provide material for the determination. This situation prevails with black locust and the locust borer.

In our search for resistant strains, we have vegetatively propagated black locust trees that are free of borer attack and have good form and high vigor. Such strains, obtained from many states, are being propagated and outplanted in experimental plots to study their resistance to borers. In all our plots thus far we have found some borer damage; however, the analysis of borer infestation data shows significant

A black locust of good form, high vigor, and free of borers is selected for propagation and use in testing our search for borer-resistant strains.

differences among several clones. Analysis by site shows two sites to be different, and each of these differs from the other two, which are similar. Thus we have found that variation exists and is influenced by site.

Our study of borer resistance in black locust will also supply information about borer attack at any stage of tree development, because we are making annual observations of attack and measurements of tree growth. For instance, we have found that some 1-year-old seedlings are attacked the year of planting.

As plot character changes—such as closing of the crown canopy—we expect changes in borer populations. The adult beetle responds positively to sunlight, but also has an air temperature preference of 85 degrees. The influence of these factors, plus those of clonal variation, remains to be discovered.

Reduction of insect pest populations by inhibiting reproduction with sterilizing chemicals has been demonstrated with cattle flies, but little research has been done with chemosterilants on forest tree pests. We are evaluating such chemicals for possible control of the locust borer, which is abundant and damaging in many areas.

In our first laboratory experiments with metepa, we have obtained complete sterility of the study insects. This chemosterilant was then evaluated against HMPA (Ent-50882), ENT-50990, and ENT-50991 with controls in 20 replications. Most successful was ENT-50990, which limited reproduction to an average of one larva from five pairs of beetles when the male was treated with 0.009 ml. of 1-percent solution. The controls yielded about 142 larvae from five pairs of beetles. In terms of egg viability, the controls showed 100-percent hatching in comparison with approximately 0.6 percent for the group treated with ENT-50990. Insect longevity was not affected by the treatment.

The practical use of some of the sterilizing chemicals is doubtful because of their possible mutagenic or carcinogenic properties. This does not apply to HMPA (also called hempa or

hexamethyl phosphoramide), which is a nonalkylating compound of low toxicity to mammals. Repeated experiments have shown that HMPA can reduce by 87 percent the number of larvae normally produced by adult locust borer beetles. This effectiveness, plus the greater stability of the compound and increased safety in its use, encourages the prospect of success in applying the sterilizing method of control to tree borers.

In evaluating oak bark beetles as vectors of the oak wilt fungus, we seek answers to three questions: (1) what is the biology of the beetles? (2) do they meet the basic requirements of a disease vector? and (3) do they disseminate the pathogen and transmit the disease?

We have found that the oak bark beetles meet some of the basic requirements of a vector for the oak wilt fungus. When beetles make successful breeding attacks (egg gallery and egg-laying completed) on oak wilt trees, the parent adults re-emerge as well as their progeny. It appears that the parent adult beetles re-emerge after attacking oak wilt trees and then attack healthy trees, thus perhaps transmitting the oak wilt fungus in the process. Preliminary studies indicate that more re-emerging parent adults carry the fungus than the progeny do when they emerge from a diseased tree.

Studies are planned to determine what form of the fungus (conidia, ascospores, mycelium) a particular group of beetles is carrying when they

Black locust from many states are vegetatively propagated and planted in research plots to study variation in borer resistance by selected trees.

emerge from a diseased tree. Studies are also being continued on the basic biology of the beetle, including seasonal activities.

Vascular and Virus Diseases

Oak wilt, a lethal vascular disease, is a potentially serious threat to production of oak lumber in the United States. Satisfactory control of this disease will very likely depend upon a more complete understanding of the life cycle of the fungus, of the means and methods of disease spread, and of the biochemical and physiologic interactions between the pathogen and the host plant.

Fungus mats formed under the bark of oak-wilt killed trees are a salient feature in the life cycle of this pathogen. They are also believed to be an important source of inoculum for spread of the disease by insect vectors. Within the range of this disease, mat production is relatively common and abundant in the North and East but relatively rare in the South and Southwest. Factors that might account for variation in the occurrence of mats are being studied.

In a cooperative study with the University of Missouri and The Pennsylvania State University, bolts cut during the summer from diseased trees in Pennsylvania and Missouri, and piled in Pennsylvania where mat production is relatively abundant, produced a few mats. Similar bolts, piled in Missouri where mat production is infrequent, produced no mats.

Six months after cutting, the bolts piled in Missouri were obviously past the mat-producing state; the bark was loose and sloughing off. The bark on the bolts piled in Pennsylvania remained tight until the following spring. Air temperature at the storage site in Missouri was appreciably higher and relative humidity was appreciably lower than in Pennsylvania during July, August, and September. Sapwood moisture content decreased significantly faster in the bolts in Missouri than in those in Pennsylvania. Invasion by saprot organisms, chiefly *Hypoxylon punctulatum,* occurred earlier and was more prevalent in the bolts in Missouri than in those in Pennsylvania.

Several countries will not accept oak logs for import if they originate within the known range of the oak wilt disease in the United States. Studies to perfect a treatment that will make such logs safe for export have continued. Fumigation with methyl bromide at concentrations of 5 pounds per 1,000 cubic feet of fumigation chamber space for 7 days at 75°F. or for 1 day at 100°F. has killed all the fungus in infected logs, in repeated studies. Treatments at lower concentrations, lower temperatures, and of shorter duration have failed. Results of initial trials in which logs are heated by hot air or hot water dip suggest that heat alone, in the 110-130°F. range, may be equally effective.

To study the biochemical character of oak wilt, we need a reliable measure of the various stages of disease development from initial infection through leaf symptoms to death of the tree. To this end, diseased and healthy oak seedlings, maintained under controlled conditions in a growth chamber, are being measured and compared. Factors being considered are transpiration, leaf volume, ash weight, resistance to water movement through stems, and the activities of certain enzymes. It was found that, as the disease progresses, transpiration decreases rapidly over a short period of time. Little invertase activity was detected, but it was generally greater in diseased than in healthy oaks (this was also true in 2-inch diameter oaks in the nursery).

Enzyme and toxin production by the pathogen in liquid culture is being studied. A toxin-purification procedure, relying chiefly on column chromatography, is being developed.

Recovery of the crown of this chlorotic dwarf white pine tree was effected through the use of chambers equipped with filters designed to control the entry of atmospheric pollutants whereas the symptomatic lower portion was exposed to ambient air.

Cankers, Heartrots, and Physiogenic Diseases

Within the past 60 years, chlorotic dwarf, a widespread foliar disease of eastern white pine *(Pinus strobus* L.), has been the subject of considerable confusion about its symptomatology, etiology, and relation to other white pine needle blights. Chlorotic dwarf has been attributed to drought, natural competition and suppression, moisture imbalances, nutrient deficiencies, poor planting practices resulting in root balling, a possible physiological-genetic complex, fungus root rot, feeding by sucking insects, lack of root mycorrhizae, and viral infection. None of these concepts has ever been experimentally proved and chlorotic dwarf has continued to be an enigma.

In our studies of chlorotic dwarf we have sought to delineate its symptomatology, determine its cause, and propose measures for its control. We investigated several possible causal agents, including insects, fungi, malnutrition, virus, and moisture stress. We found that air pollution is primarily responsible for causing chlorotic dwarf through its harmful action on foliage of genetically susceptible white pines.

In the spring of 1965, a trunk canker was observed in a planting of Wisconsin #5 poplars, a clonal selection of eastern cottonwood *(Populus deltoides* Marsh.). Continued inspections of neighboring stands showed two clones of aspen-popular origin similarly affected. These clones were natural hybrids between bigtooth aspen *(P. grandidentata* Michx.) and white poplar *(P. alba* L.). Pathogenicity studies established *Fusarium solani* as the cause of this disease. This fungus has become an important pathogen on forest trees, and poses a threat to hardwood plantations in the future.

A study begun in oak-hickory forests several years ago to determine decay losses, the identity, frequency, and severity of decay organisms, and to evaluate the factors associated with decay processes, is continuing. Over 3,000 trees have been cut, dissected, and studied on 124 one-fifth acre plots in Ohio, Kentucky, Indiana, and Illinois. Over 40 different identified species of

wood-destroying fungi have been isolated. Two species of Stereum *(S. frustulatum* and S. *gausapatum)* accounted for over one-third of the decay. Almost 40 percent of the decay fungi entered through fire scars. Other important means of entry were branch stubs 4 inches and larger, open branch bumps, and mechanical wounds.

Studies to determine the effects of environmental factors on the growth and activity of wood-decaying fungi were continued. In studies where wood-decaying fungi were grown under different levels of oxygen and carbon dioxide, dry weight production of the fungi decreased as oxygen concentration decreased below atmospheric levels and as carbon dioxide concentration increased from zero. To determine if this information had any merit with regard to the natural environment in which these organisms grow, the oxygen and carbon dioxide levels in trunks of living trees were measured. Levels of these gases have been found that suggest that they may influence the activity of wood-decaying fungi in living trees and under the proper conditions may play a role in inactivating decay columns.

The effect of constant temperature on the growth of decay fungi has been measured. The organisms made the best growth between 27° and 30°C. Studies to measure growth under fluctuating temperatures are planned. To determine the significance of these findings, the temperatures in trunks of living trees are being measured with probe-type recording thermographs. These measurements show that the temperatures in tree trunks respond much as soil temperatures do. They lag behind changes in air temperature, and the changes are not as extreme.

The cellulolytic enzyme system in the decay organism *Stereum gausapatum* is being characterized to determine if different systems are produced on different media. In general, the system is pH and temperature tolerant and has the highest activity at pH's between 4 and 5 and at a temperature of 50°C.

FOREST PRODUCTS MARKETING

THE program of our Forest Products Marketing Laboratory at Princeton, W. Va., underwent significant changes in 1966. Because of the size and complexity of our marketing research program, we divided this work into four separate projects.

One, under project leader Thomas W. Church, Jr., deals with primary forest products such as sawlogs and pulpwood. The second, under Donald G. Cuppett, deals with primary manufactured wood products such as lumber, veneer, and residues. The third, under Walter B. Wallin, deals with secondary manufactured wood products such as furniture, flooring, pallets, and dimension stock. The fourth, under Gilbert P. Dempsey, deals with research of a more general nature, including studies of timber resource availability, labor, and other factors important to all forest-based industries.

In addition, a project in utilization research is headquartered at the Princeton Laboratory, under project leader Charles Gatchell. Scientists in this project, which is closely coordinated with our marketing research project, conduct research to solve physical problems that limit markets for wood products. Contributions of this project are summarized in a later section of this report.

The following pages describe the work now under way in our marketing research projects, along with highlights of some individual studies.

PRIMARY FOREST PRODUCTS

Roundwood Transportation

Although roundwood transportation is only one of the elements in the flow of raw material from stump to mill, it is especially important in the rugged Appalachian Region. This is normally the most costly phase of the entire harvesting operation. For this reason, we have begun a comprehensive investigation of existing transport techniques to determine if and how significant efficiencies can be achieved.

We are analyzing the machinery and techniques used in building wood roads, loading products, hauling these products by road and rail, and unloading them at mills. Our study sample included 185 sawlog operators supplying logs to 100 sawmills, and 138 pulpwood producers supplying 8 paper mills, in 6 Appalachian states from Maryland southward. Sawlog operators were proportionally sampled in 3 mill size-classes according to daily production. Pulpwood producers were sampled according to the paper mills' daily capacities.

Road-building. — Four out of five logging contractors built ½ mile or more of woods roads on their present boundaries this year. However, road-building was more extensive on timber

Double-tandem "piggy back" pole trailer capable of hauling 4,000 board feet increases the efficiency of long distance transport.

tracts supplying the larger mills: 85 percent of the contractors working for large mills constructed woods roads, compared to 70 percent of the operators supplying small mills. Most logging contractors simply bulldozed their roads, seldom surfacing, draining, or widening them.

Loading.—Eighty-six percent of the sampled contractors hauling to small mills loaded their trucks by hand, mostly from rollways. About half the operators trucking to medium mills also hand-loaded, but most contractors hauling to large mills used mechanical loaders. The mobile crane with cable and tongs was the most common piece of mechanical loading equipment.

Hauling.—About 70 percent of the contractors hauling to small and medium sawmills used light single-axle straight trucks, hauling 1,000 to 1,200 board feet per load. But at large mills, only 1 out of 5 contractors used these smaller trucks. Seventy-five percent of the operators hauling to the large mills used tandem-axle straight trucks that commonly carried twice the volume loaded on the smaller trucks. A few contractors have recently purchased tractor-trailers or pole trailers to deliver tree-length logs to the large mills. Average one-way hauling distances from landings to mills were: 11 miles for small mills, 17 miles for medium mills, and 27 miles for the large mills.

Unloading. — Nearly all contractors delivering logs to small mills unloaded their trucks by hand, and few of these trucks were equipped with safety trip stakes. At medium mills, this same practice was common: 80 percent of the contract haulers unloaded by hand. Even at large mills where mechanized equipment is normally available, 37 percent of the log deliveries were hand unloaded. In some instances, logs were rolled off by hand even though powered equipment was available. Where unloading was mechanized, forklift trucks were the only devices used.

This analysis of transport equipment and procedures will serve as the basis for future research on specific phases of roundwood transport that show the greatest need for improvement.

Markets for Low-Grade Logs

Nearly everyone familiar with eastern hardwood resources is aware of the amount of low-grade timber in the forest. When this timber is logged and sawed into lumber, the dollar returns seldom cover the harvesting and manufacturing expenses. So sawmill operators must seek and cut the better grade trees. Thus the volume of low-grade trees continues to increase while the volume of higher grade timber gradually declines.

A common concern of both industrial resource managers and the primary forest industries is the oft-voiced complaint, "What can I do with my low-grade timber?" Even the better logs have some low-grade lumber concentrated around the pith.

Our research has indicated that cant products such as crossties, mine materials, and industrial timbers can be manufactured and marketed profitably. But our early studies did not show the percentage of factory-grade hardwood sawlogs that were suitable for cant manufacture, nor the maximum dimensions of these potential sawed timbers. Investigations are now under way to provide this information.

Interim results from red oak sawlogs sampled at three West Virginia mills revealed that 80 percent of all log grades and log sizes were acceptable for the manufacture of at least a 5-by-5-inch cant. Of the 20 percent unacceptable for the manufacture of structural timbers, about one-third were too small, one-fifth were rejected for external defects such as sweep, and nearly one-half were unsuitable because of core defects such as rot.

We observed a strong relationship between log grade and the percentage of logs suitable for cart manufacture. The hearts of nearly all the grade 1 logs could be sawed into 5-by-5-inch

Black template shows how sawlog sweep reduces the size of a timber that could be sawed from a straight log (white template).

or larger cants, but one-seventh of the grade 2 logs and one-third of the grade 3 logs were unsatisfactory for this use.

The potential maximum size of sawed timbers was also influenced by the grade of acceptable logs. For instance, most grade 1 logs could be sawed into at least an 8-by-9 inch cant whereas only half of the grade 1 logs could be sawed into 12-by-12-inch cants. In log grade 2 , 86 percent of the logs could be sawed into cants 6-by-7-inches but less than half of the logs could be cut into 8-by-9-inch or 10-by-10-inch cants. Grade 3 logs seldom allowed the manufacturer of cants larger than 8-by-9-inches.

PRIMARY MANUFACTURED WOOD PRODUCTS

Although markets were strong for all hardwood products in 1966, a significant down-turn in prices for the common grades of oak lumber began during the last half of the year. Since oak constitutes nearly half of the Appalachian hardwood production, our research has been concentrated on alternative markets for sawmills manufacturing these species.

In 1966 we continued research designed to help improve production and seasoning practices at sawmills. Part of this research is being done in cooperation with The Pennsylvania State University, West Virginia University, the University of Maine, and the University of Massachusetts. The following summaries illustrate the research conducted by this project.

Markets for Mine-Timber Materials

Mining has long provided an important market for low-grade hardwood timber. However, the markets for mine timbers have been declining for more than a decade. Some of the reasons for the decline in these markets are: a decline in the tonnage of bituminous coal deep-mined, the use of roof-bolting, use of substitute materials such as concrete, and use of new mining machines.

The purpose of our research here is to describe and analyze present market conditions and to forecast the future trend in the use of wood by the bituminous coal industry.

The purchasing agents of approximately 50 mining companies in West Virginia, Kentucky, and Pennsylvania will be randomly selected for personal interviews. An analysis of nine companies has been completed, and the results indicate that an inadequate quantity of mine-timber materials are being supplied in many localities. Also, it was found that mine-timber materials often fail to conform to the specifications of the mining engineers, which has led to dissatisfaction with the product.

Most of the mine-company officials interviewed predicted a leveling-off of the quantity of wood used per ton of coal mined, rather than a continuation of the present decline. Since these officials also predicted that the future production of soft coal will gradually increase, an increase in the total quantity of mine-timbers used can probably be expected.

The Supply and Demand for Yellow-Poplar

Begun this year, this research is designed: (1) to forecast future markets for yellow-poplar products, by kind and volume; (2) to forecast future supplies of yellow-poplar timber; and (3) to determine imbalances between market needs and timber supplies as guides to marketing recommendations.

Representatives of the furniture industry have expressed their concern for the supply of yellow-poplar lumber. Veneer manufacturers are finding it more difficult to obtain yellow-poplar

Old-growth yellow-poplar logs are now rare in the Appalachian region. This tree contained five 12-foot logs scaling over 8,000 board feet. Kanawha County, West Virginia, 1964.

logs in quantities of suitable grades. The competition among veneer-log buyers is intense.

Sawmills, too, find that they are involved in this competition for yellow-poplar logs as grade 1 and some grade 2 factory-lumber logs are being siphoned off into veneer-log markets because of better prices. Top prices for yellow-poplar veneer logs exceed lumber-recovery values for sawlogs of veneer-log quality. Hence many sawmill operators are selling their high-grade logs for veneer rather than sawing them. Some people believe that this explains the apparent shortage in yellow-poplar lumber supply.

From data compiled to date, we have a partial description of trends in yellow-poplar timber production and use. For example, forest-survey statistics show that during the decade 1952-62 inventories of poplar growing stock and sawtimber have increased considerably, yet the harvest has declined by over one-third.

Yellow-poplar is cut principally for sawlogs for production of lumber. However, the volume of yellow-poplar being cut for pulpwood is increasing steadily, particularly in the South.

Wood-consuming industries use yellow-poplar more for lumber than for veneer, plywood or boltwood. The furniture industry is the largest user of poplar lumber. In 1960 this industry consumed 48 percent of all produced. The container, millwork, and pallet industries are other large users; but all these, except the pallet industry, used less lumber in 1960 than in 1948. What the future holds for yellow-poplar in these lumber markets is one of the principal concerns of our study.

To determine future market requirements, estimates of consumption of lumber, veneer and plywood, dimension, and pulpwood will be forecast for the years 1970, 1975, and 1980 by correlating end-use product (furniture, pallets, woodpulp, etc.) consumption with estimates and projects of population, gross national product, industrial production, and other economic indicators.

SECONDARY MANUFACTURED WOOD PRODUCTS

In this project we are doing research on hardwood flooring, pallets, furniture, dimension stock, and urban rehabilitation. Some of the work and results of this project are reported below.

Hardwood Flooring

Nationally about 20 percent of all hardwood lumber produced is used in the manufacture of flooring. But hardwood flooring, like many wood products, is being replaced by substitute materials. Between 1955 and 1963, use of wood in the residential flooring market dropped from 68 percent to 34 percent, a decrease of over 375 million board feet per year. Because the hardwood flooring industry represents such

a vital segment of the wood industry, especially in the Appalachian Region, we have given high priority to research designed to maintain or expand the markets for this product.

The first step was to compare maintenance and repair costs for different residential flooring materials. In our research we have found that hardwood flooring possesses longer wear life, lower yearly maintenance costs, and lower long-term costs than the other commonly used flooring materials. Thus it appears that the declining demand for hardwood flooring may be due more to the active promotion and merchandising of competing materials than to any actual competitive disadvantages of wood.

Three new lines of research on hardwood flooring were undertaken during the year. This research is designed to:

- Improve the competitive position of hardwood flooring through increasing the efficiency and effectiveness of distribution channels.
- Determine the factors affecting the selection of flooring materials used in educational buildings.
- Determine the factors that limit the use of hardwood flooring in mobile homes.

Wooden Pallets

The wooden-pallet industry, like the hardwood flooring industry, uses approximately 20 percent of the total hardwood lumber production, requires the lower grades of lumber, and is composed of numerous small producing units. So wooden pallet research has high priority in our program.

Research on markets for wooden pallets in the steel industry that we completed during the year shows that steel-industry officials are well satisfied with the pallets they receive. The role of wood in this market seems assured. But substitute materials are becoming more competitive; and the wooden-pallet industry can expect to maintain or accelerate its economic growth only by continual improvement of production efficiency, product quality, and merchandising techniques.

Our research on the Armed Forces market for wooden pallets continues. During the year a report, "Wood Pallet Requirements and Purchases by the Armed Forces," was prepared to explain military procurement procedures and problems to the wooden-pallet producers in an effort to stimulate production of pallets for this growing market. We found that the Defense General Supply Center at Richmond, Virginia, now buys about 360,000 wooden pallets per month, compared to 115,000 per month in 1965. Approximately the same number of pallets are bought by firms that supply goods on pallets to the Armed Forces, and most of these pallets are re-used by the Armed Forces.

Markets for wooden pallets in the

This machine now makes it possible to drive wooden highway guardrail posts fast enough to compete with steel posts.

brewing industry also are being studied. Data have been collected but computation and analysis have not yet begun. However, it does appear that large breweries handle most beer cases and kegs on many different kinds and sizes of wooden pallets. Most breweries have a close working relationship with several pallet suppliers and believe they are receiving high-quality pallets at a fair price.

Use of wooden pallets in the food industry is the subject of cooperative research with Better Management Services. Evaluation of the performance of hardwood pallets is well under way and about one-third of the data have been collected.

Our research in these areas is just getting under way. We are identifying those marketing problems in the furniture and dimension industries that we can help solve through research. Findings to date indicate that research on consumer preferences and distribution of furniture products is most in need of study. Research has been started on the use of dimension stock by the southern furniture industry. And we are exploring the potential markets and economics of hardwood plywood cut from the lower-grade logs. Parts of our research in these product fields are being done in cooperation with the Virginia Polytechnic Institute and North Carolina State University.

Urban-Rehabilitation

Our research here resulted in the development of a floor-leveling system designed specifically for use in the New York City rehabilitation project. This system, which incorporates the use of urethane foam as a base for wooden screeds, appears to be the most rapid and economical method yet devised for establishing a new level floor surface in renovated apartment buildings.

Further research in this area has been postponed pending presentation of the findings of the Forest Service Task Force Committee on Urban Rehabilitation.

INDUSTRIAL OPPORTUNITIES

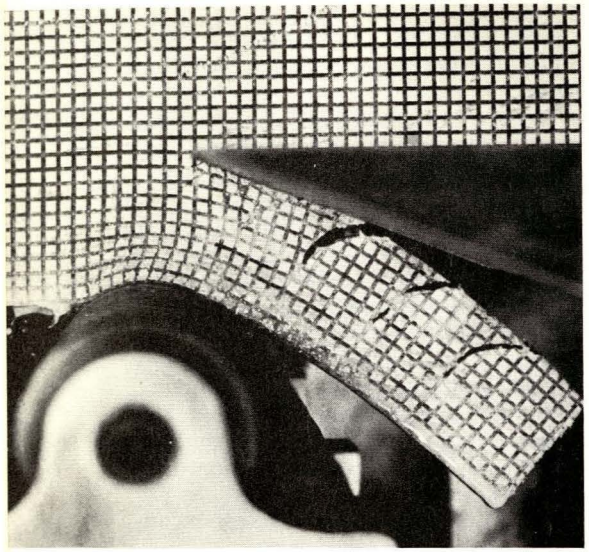
The economy of the Appalachian highlands suffers from a lack of industry and job opportunities. Expansion of the forest-based industries could be a major factor in improving the economy in this and other depressed areas in the hardwood regions. However, the physical presence of a timber resource in a region is not enough to assure wood-industry expansion in that area.

Of equal importance are those factors that relate to the economic availability of the timber resource; for example, forest landowners' attitudes toward selling timber or using the forest for other purposes; volumes of timber in sufficient quantities per acre to be logged economically; and location of timber in respect to terrain and road systems.

Other factors such as availability and quality of labor, transportation, and community facilities affect the location decisions of industry, often more than the existence of timber supply. In 1966 we started new research on these important problems.

Timber Availability

Wood-using firms are becoming concerned about open-market timber supplies. Until recently, wood for industrial use could be obtained easily; supply problems were usually a result of deficiencies in procurement systems rather than a physical timber shortage. But changes in technology and land-ownership patterns have affected open-market timber supplies. As a result, wood-using firms find it difficult to make realistic decisions concerning



The apparent technological problems in slicing wood up to 1-inch thick are being solved by machining research. One job is to evaluate the commercial application of such a process.

year-to-year operations and to plan for expanding their mills or establishing new mills.

Many of the factors that affect the open-market timber supply are now being defined and analyzed; and one of the more important appears to be the goals of the landowner. For some owners the social, institutional, and economic environment limits interest in selling timber. Recreation objectives overshadow many plans for selling and cutting timber on some forested areas. Other factors such as small scattered forest ownerships, limited access, and low volumes per acre also affect the open-market timber supply. Timber on such lands cannot now be harvested economically, and for all practical purposes is not available for industrial use. It can make no contribution to the economy for many years.

Once the important factors are analyzed and understood, additional research will be undertaken to provide industry with useful information about the grades and types of timber that are economically — not just physically — available.

New Products and Processes

The idea of slicing rather than sawing lumber-like products appeals to primary wood manufacturers, especially those who saw thin material. It is an old idea, but until recently our technology did not allow slicing the thicker products.

The Forest Products Laboratory started research on thick-slicing wood about 1960 and called the product slicewood. They have since shown that, in experimental situations, up to 1-inch thick material can be sliced without serious defect.

As technical research on slicing continues, one will be looking at production costs and potential markets for slicewood. Since certain investment decisions demand knowledge of machine capacities at different levels of production, we began the work by investigating the response of slicer output to changes in other production variables. An equation was developed to help understand the interaction of these variables. It should give clues to the most efficient ways of spending limited capital to improve slicing systems. For example, if increased output is a goal, the manager might add machines, increase slicing rate, decrease loading time, or change flitch size. The formula allows him to estimate the effect of his decision on production rate.

The next step is to collect market information and cost data. This research will provide: (1) unit costs at several levels of production; (2) comparison of these with the costs of making the same products by conventional means; (3) the levels of capital in-

vestment that are allowed for slicing and drying; (4) the sensitivity of product price to changes in production costs; and (5) general information about potential markets for slicewood.

Another FPL-developed product will be evaluated. This is a ceiling tile (made from pulpchips) that can be styled in a wide range of colors and textures. Our job will be to see if there is room for it in the competitive market—there already are more than a hundred other ceiling products.

On the surface, the product and its potential look good. But we would rather obtain negative results than to even suggest commercialization based on appearances — especially since the ratio of new product failure to success is something like 7 or 9 to 1. The objective of our work in new wood product and process evaluation is to reduce that ratio.

We are now conducting an analysis of the structure and marketing problems of the Christmas tree industry in the eastern United States to determine the factors causing economic loss, and to recommend research to combat these losses.

Preliminary results indicate that losses in the industry result from a number of factors, the most important being surplus trees. Some retailers are forced to discard two trees for every three they sell. If 15 percent of the trees cut annually in the United States are not sold, the result is a nationwide loss of $17 milion, assuming a retail value of $3.50 per tree. Eventually these costs must be absorbed by the consumer.

Our analysis also indicates a need to evaluate the competitive position of natural trees. In some markets, artificial trees represent 7 to 34 percent of the trees purchased, and their use is increasing.

Industrial Location

Closely associated with industrial expansion in the Appalachian Region is the series of decisions involved in industrial location. A more thorough knowledge of this process will guide development agencies and research organizations to channel efforts in more useful directions. As an initial step, the recent location decisions of a primary forest-products manufacturer will be studied. In this case study we will analyze the location decisions from the time the idea to locate a plant was adopted through to the final decision on a specific site.

Christmas tree shearing and use of genetically superior trees has resulted in plantations like the one above. Prior to 1940 almost all Christmas trees were harvested from unmanaged or wild lands. Today 4 out of every 10 trees found in the marketplace originated on farm plantations.

UTILIZATION RESEARCH

THE reorganization previously mentioned gave the Station four utilization research projects. These are:

1. Wood product improvement for New England. Dr. Richard Jorgensen, project leader; Upper Darby, Pa.
2. Log and tree grades for northern softwoods. Myron D. Ostrander, project leader; Upper Darby, Pa.
3. Hardwood log and tree grades. Roswell D. Carpenter, project leader; Columbus, Ohio.
4. Hardwood product improvement. Charles Gatchall, project leader; Princeton, W. Va.

Results from some of the research done in these projects during 1966 are reported below.

WOOD PRODUCT IMPROVEMENT PROJECT FOR NEW ENGLAND

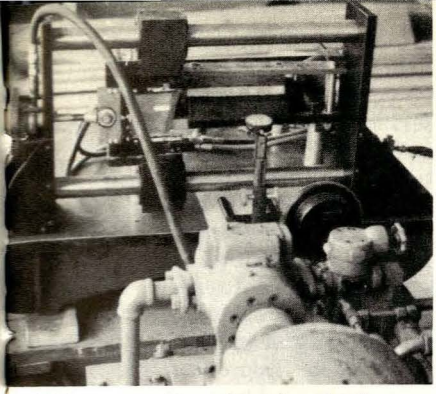
This year we concluded our research on outdoor storage of hardwood chips. Determination of pulp color due to treatment of stored chips with chemicals was the final phase. The following materials showed good capabilities for preventing undesirable color in stored chips: sodium fluoride, sodium azide, mercaptobenzothiazole, and p-benzyl oxyphenol. No work was done to determine the effects of these chemicals on the pulping processes or on the final product. It was felt that the amounts used are so small per ton of wood material that effects would be minimal.

Longitudinal case-hardening has bothered several producers of specialty products because of the distortion that occurs in recut boards that apparently had been satisfactorily kiln-dried. No stresses were indicated in standard prong tests for case-hardening, yet the boards became distorted when cut lengthwise. Practically 100-percent relief was obtained by a conditioning period of 17 hours at 180°F. dry bulb and 165°F. wet bulb. No reverse case-hardening occurred in the 3-inch wide slats that were processed. Since all longitudinal case-hardening reported had been in relatively narrow stock, it was assumed that this type of conditioning treatment will solve the problem.

Slicing roundwood into thicker-than-veneer pieces seems to offer more rapid and more economical production of certain products than sawing does, but there are many unknowns yet to be solved before slicing will be commercially feasible. In a cooperative study with The Pennsylvania State University the results of drying ½-inch yellow-poplar slices by several methods were evaluated.

Analysis of data is not yet complete, but some unusual results have been noted. In high-frequency oven drying, for example, the sliced pieces consistently dry more rapidly than the matched sawed samples.

One of our scientists who had previously assisted in timber-quality characterization work has been stationed at The Pennsylvania State University for a 1-year period. He will conduct research there on the wood quality of effluent-watered conifer trees. The results are expected to provide guidelines



Slicing machine for the kerfless production of thick slices.

for the accelerated production of conifer wood by continuous watering and fertilizing.

Adverse reports about some recent applications of polyurethane resins on hardwood strip flooring prompted a study of several resins and their use on this type of flooring. Polyurethane resins have been used as finishes on hardwood floors for about 20 years, one of the first of these being known as "bowling alley finish". These materials are expensive but produce extremely durable finishes that more than compensate for the initial cost because they need no waxing or other maintenance.

The results show that the problem is directly related to the viscosity of the resin. If the resin is too thick, it lies upon the surface of the wood in excessive quantities and adjacent flooring strips become glued together. Then, when the house is heated the shrinkage of the wood becomes cumulative across many strips until the weakest joint opens up into a large separation.

Our research verified that these resins are excellent for strip flooring if they are applied thin enough that they do not form bonds between adjacent strips.

The Northeast uses more wood flour —wood in a very fine particle form— than any other part of the country. At the request of some members of the industry we have made several short-term studies directed toward developing wood-flour standards and associated testing methods. Results of this work are not yet available.

HARDWOOD PRODUCT IMPROVEMENT PROJECT

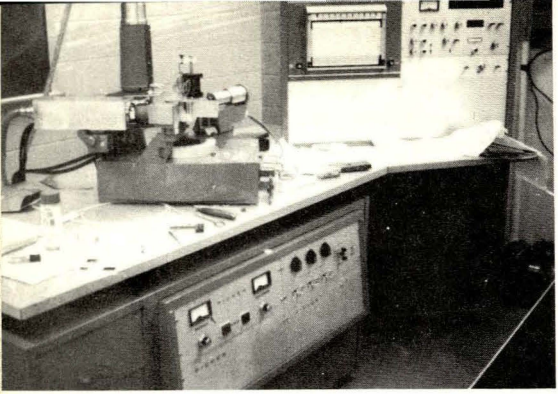
The main objective of hardwood product-improvement research at our Princeton Forest Products Marketing Laboratory is to increase the markets by improving product utility and manufacturing processes. As much as possible, priorities are based on industry needs as determined by market research. In turn, marketing researchers evaluate the economic potential of new products or processes developed by the project.

Installation of Highway Posts

Three years ago, a market analyst found that wooden guardrail posts were no longer used in new highway construction in West Virginia, even though wood was less costly than any other guardrail post material—including the costs of installation. Wooden posts were not used because they could not be installed quickly enough. On the average, steel posts could be driven at 30 posts per hour while wooden posts could be handset at 10 posts per hour.

Our Laboratory technologists cooperated with a guardrail subcontractor and an equipment manufacturer to develop a mobile power post driver.

For a realistic demonstration of the machine, conditions typical of an actual guardrail post-installation job were required. The State Road Commission of West Virginia provided four driving sites considered typical of southern West Virginia. Posts were installed to meet the Commission's specifications



X-ray spectograph for the study of wood quality.

for plumbness, alignment, spacing, and freedom from damage. A well-trained crew, experienced in all types of post-installation work, was trained to use the new driver before the study was begun. Approximately 280 posts were installed.

We found that wooden posts can be driven on any site where steel posts can be driven. They can also be driven on some sites where steel cannot and where an auger cannot be used. With the machine used, rates of installation of aligned guardrail posts up to 35 posts per hour can be expected. Installed cost is $1.00 to $3.25 less per post than that for power-driven steel posts. The driving action causes no damage to the tops of properly machined posts.

Railroad Crossties

Market analysts have found that the $100 million annual market for treated wooden railroad ties and timbers is in danger of being lost to substitutes. Demand presently exceeds supply, and indications are that this will continue. Competition from concrete ties is becoming more severe. If wood is to hold its place in this market, research must find ways to help increase the available supply of wood crossties, and to reduce the cost per mile of track.

Our first study of this involves a service test of larger crossties: 8-by-12-inch ties as compared to the 7-by-9-inch ties in conventional use. This increase allows a one-third reduction in the number of ties and thus a reduced cost per mile of track.

One hundred twenty-six of these larger crossties were air-seasoned to an average moisture content of 50 percent. In order to reduce end checks and splits, two end-treatments were applied: (1) 2-inch deep holes, ¼-inch in diameter and spaced on 1-inch centers, were drilled into each end of the ties and (2) a standard wax emulsion was applied to each end of the ties.

After air-seasoning, 110 of the ties were selected for service tests by a major railroad. These ties were pressure-treated with creosote and are being installed in a mainline track on 30-inch centers. Final evaluation of these crossties will require many years.

New Manufacturing Systems

Details of our research to develop a system for converting low-grade red oak bolts directly into ready-to-use pallet parts were given in last year's Report.

The question now being studied is: What sawing technique will give the highest yield of pallet parts? To get an answer, 6,000 board feet of factory-grade 3 red oak logs were bucked into bolts, and the boards resulting from live-sawing these bolts were diagrammed to mark the location of defects. A computer program was written to theoretically rebuild the bolts and then saw them by five different sawing techniques. The output of this computer program will be used in conjunction with a second computer program to find the number of pallet parts that can be obtained with each sawing technique.

Another important step is drying. Pallets made from dry deckboards are superior to those made from green deckboards. Since conventional han-

dling is too expensive for drying short lengths, we are searching for a way to dry palletized loads of short lengths. They can be either air-dried or forced-air-dried. They key to palletized drying is a special strapping that can be stretched around the load. As the parts dry, the strapping shrinks. It can be retightened if necessary before the load is dried.

LOG AND TREE GRADES

Northern Softwoods

In our northern softwood log and tree grade project, we began research aimed at developing standard lumber log-and tree-grade specifications for eastern hemlock. Although hemlock is a relatively low-value species that does not justify the establishment of a complex grading system, we do need more accurate predictors of its merchantability so we can satisfactorily estimate net volume and value of logs and trees.

The difficulty in obtaining an accurate measure of the net volume and grades of hemlock logs and trees is due to the occurrence of ring shake, a common characteristic of the species. Hidden in standing trees and therefore always difficult to evaluate, it also presents a problem in evaluating cut logs. Recent investigations by one of our pathologists, Dr. Alex Shigo, have indicated an association between ring shake and sapsucker damage (bird peck). Other factors may also be involved, such as growth rate and changes in growth rate throughout the life of the tree. Further examination of these relationships will, we hope, result in better methods of ring-shake detection and evaluation.

The first of a series of hemlock sample trees has been collected. The sample consisted of 126 trees (producing 441 logs) from five different locations in north-central Pennsylvania. Detailed stand and tree characteristics were recorded, and the usual log diagrams were made. The logs were processed into standard lumber at the Blair Lumber Company, Barbours, Pa.

Final analysis of the data cannot proceed until the dry-dressed grading of the lumber is completed. However, preliminary examination of the green lumber-grade data indicates a significant relationship between lumber degrade due to ring shake and tree age, log position, and severity of bird peck. It is expected that additional shake due to bird peck will be observed in the lumber after drying. When dry-dressed lumber-grade data are available, we will further evaluate effects of growth rate, growth-rate changes, tree lean, sweep, etc., on severity of shake.

Another interesting observation was the effect of stump height on lumber quality of butt logs due to the common occurrence of butt sweep, fire scar, and shake in the lower 2 or 3 feet of eastern hemlock. It was apparent that the accepted practice of cutting low stumps should not be generally recommended for hemlock. In many cases stump heights of 2 feet would have resulted in appreciably higher grade lumber than was obtained from the low stump. Volume losses due to higher stumps would be more than offset by increase in lumber value.

Additional sampling of eastern hemlock is planned for New England, the southern Appalachians, and the Lake States.

Final analysis of the eastern white pine log-grade data is incomplete but log-grade yield data by geographical areas (New England, the southern Appalachians, and the Lake States) are now being processed.

Project personnel cooperated with the Northeastern Lumber Manufacturers Association, the Northern Hardwood and Pine Manuafcturers Association, and the Canadian Lumbermans Association in a second lumber-grade-comparison involving 21,000 board

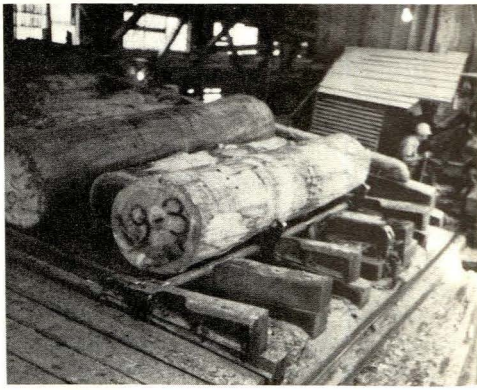
A HARDWOOD TREE AND LOG GRADE STUDY

Selecting sample trees.

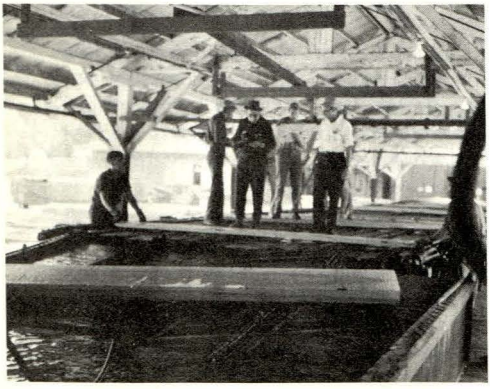
Diagraming logs.

Sample logs at sawmill.

Sawing sample logs.



Inspecting and tallying lumber.



Log grade training session.

feet of eastern white pine lumber. We are analyzing the data and will prepare a report to be presented at Grade Committee meetings of the several associations for the purpose of discussing the possibilities of lumber-grade standardization within the three groups.

Hardwoods

Another ambitious field season was carried out by our hardwood log and tree grade project. A major reason for our accomplishments this past year was the excellent cooperation received from other branches of the Forest Service as well as the State of Ohio. Eight National Forests were called on for a large share of the field work.

Scaling studies were conducted in Alabama, Georgia, Mississippi, North Carolina, Ohio, Tennessee, Vermont, and West Virginia. All these were made on National Forest land except for that in Ohio, where the sample trees were supplied from a State Forest. The major objectives of this research were: (1) to supply lumber-grade-yield data to accompany hardwood tree grades, (2) to extend existing log grade-lumber yield data to species not previously investigated, and (3) to accumulate additional hardwood log-defect information. This phase of investigation now is the major part of our research.

The ten hardwood species studied were beech, yellow birch, black cherry, red maple, sugar maple, chestnut oak, northern red oak, overcup oak, white oak, and yellow-poplar. The oaks received the greatest attention: 610 trees, yielding 1,754 logs, were processed. The other species accounted for 270 trees, yielding 793 logs. The 25 commercially important oak species have been stratified into groups based on value separations, and lumber-grade yield tables by log grade are being prepared for each of these groups.

The year's program included several achievements in publication and education. A paper on hardwood log classes and grading, illustrated with slides, was presented at the annual winter meeting of the Ohio Chapter, SAF. Another paper was presented at the Kentucky Governor's 3rd Annual Conference on Forestry. Two 2-day training sessions in log and tree grading of hardwood and pine were conducted at Asheville, N. C., and Jackson, Miss. A conference was held with the Secretary and Log Grade Committee chairman of the Northern Hardwood and Pine Manufacturers' Association to consider whether the Association should adopt the Forest Service standard hardwood log grades for factory lumber as standard for the Association. Evaluations have been made at several member sawmills, and the Committee will meet soon to prepare a recommendation for submission to the Association.

A task force, including representatives of the Forest Products Laboratory and our insect and disease research staff, dissected 19 oak trees (4 species) to determine methods for investigating stains in oak and relating them to exterior indicators. All trees exhibited stain in some form, and a possible cause could be assigned for every occurrence of stain. For the past year we have been tallying all stained oak lumber in our oak studies in order to get an idea of stain frequency.

Individual yield tables for in-service use were prepared for yellow birch, sugar maple, black cherry, beech, red maple, and northern oak.

FOREST ENGINEERING

OUR forestry engineering research staff at Morgantown, W. Va., moved into our new Forestry Sciences Laboratory on December 14, 1966. The building is located on a 2.6-acre tract leased by West Virginia University to the Federal Government. It houses our engineering project, a wildlife project, and a small staff of State and Private Forestry specialists. The building includes a conference room, library, instrument, wildlife, and photographic laboratories, a drafting room, and offices. The library collection on logging and harvesting is already well established.

SYSTEMS ANALYSIS

The most significant work we conducted this year was research with wheeled skidders. In this research a Franklin Model 130, a Clark Ranger Model 664, and a Timberjack Model 225, were subjected to an extensive series of trials under actual logging conditions in the Fernow Experimental Forest. Use of these diesel-powered machines was provided by the manufacturers.

Instrumentation for this work included a precision electronic recording oscillograph, other electronic or electron-mechanical devices, load cells and special transducers, mechanical dynamometers, soil test apparatus, and other scientific equipment.

Measurements taken included weights of logs, and the force required to winch in logs of various sizes and species under actual operating conditions. Terrain was classified by a new system developed at the Laboratory. Skidroads were profiled, and distances from landing were staked. The slopes varied from 10 to more than 40 per-

The new Forestry Sciences Laboratory at Morgantown, West Virginia.

Each log was weighed as it was loaded on a truck.

cent. Two experimental areas having different soil conditions and several variations in slopes were established for this work.

Except for the first few days of operation, all of the skidding phase—from choker-setting to release at the landing—was done by the engineering project staff. Production ranged from 8,000 to more than 30,000 board feet per day per skidder.

This work was part of a larger systems-analysis study. Less spectacular phases were conducted on loading and other aspects of harvesting problems. Analysis of data taken is not expected to be complete until the summer of 1967. Results will be published as they become available.

Group of small logs being skidded to landing.

A large maple being winched to the skid-road. Note that the front wheels are off the road service.

Pull capabilities were determined to obtain complete data on each skidder.

COOPERATIVE RESEARCH

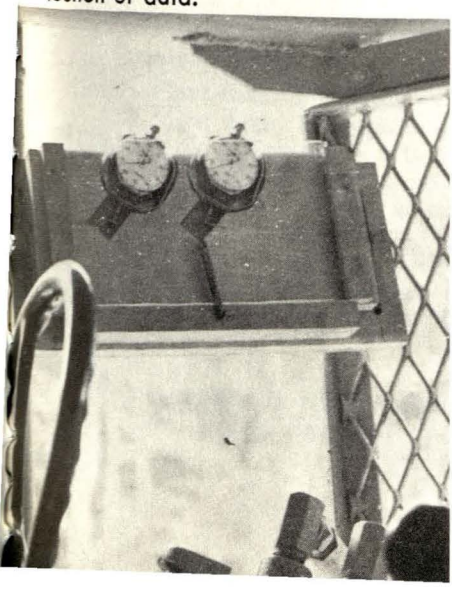
The following cooperative engineering research was in effect between the Station and West Virginia University:

- A preliminary investigation into the cutting action of chainsaw teeth. This research has already been developed to the point where, for the first time, the forces in all three planes acting upon a chainsaw tooth cutting across grain in wood have been isolated and measured.
- Research to determine the feasibility of utilizing gas generators as sources of power for portable logging tools.
- Research into the possibility of adapting revolutionary new internal combustion engines as power sources, as well as new concepts of power-generating devices.

Skidroads were narrow in this steep terrain.

- Research to identify and describe hydrologic environmental conditions that affect operating conditions in the forest.
- A theoretical study of the practicability of utilizing belt conveyors and mechanical conveying devices in Appalachia as a means of conveying large volumes of material from forest to mill.
- A preliminary theoretical study of recent advances in explosives, slow-burning propellants, combination reactive fuels, and more exotic fuels to determine feasibility for adaption to forestry operations. Consideration is being given to energy available, energy release rates, and probable safety factors.
- A preliminary study of the modification of the Zimmerman Process for producing power for forestry operations.
- Research on the feasibility of using wood as a source of power.

Stopwatches mounted in operator compartment of a skidder for collection of data.



PUBLICATIONS

in 1966 by staff members and cooperators of the Northeastern Forest Experiment Station, Forest Service, U. S. Department of Agriculture.

Alicandri, James F.

1966. **Locomotion of forest vehicles.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 56-63, illus.

Describes soil factors that affect the location of vehicles used in the forest. Gives means of simple field measurements with which to determine the trafficability of roadways for both track-laying and wheeled vehicles. Vehicles are classified according to their pulling or hauling ability in various footing conditions.

Banks, Wayne, G., and Fred E. Holt.

1966. **Who starts forest fires in Maine — and how?** U. S. Forest Serv. Res. Note NE-51, 4 pp. NE. Forest Exp. Sta., Upper Darby, Pa.

Results of a study to determine how the fires in Maine started and who or what started them. About 90 percent of the forest fires in Maine are man-caused.

Barger, J. H.

1966. **Research with systemics.** Soc. Munic. Arborists Proc. 2(1): 25-28.

Discusses systemic insecticide research, with emphasis on shade tree protection. A brief history of the development of systemic insecticides; the experimental variables a researcher considers when using systemics; the advantages and disadvantages of systemics in shade tree protection; and plans for future research with systemics.

Berg, William A.

1966. **Plant-toxic chemicals in acid spoils.** *In* Pa. State Univ. Coal Mine Spoil Reclamation Symp. Proc. 1965: 91-94.

The possible toxicity to plants of high ion concentrations of hydrogen, aluminum, total salts, iron, and manganese was studied on acid coal-mine spoils. Although pH is commonly used to decide what species to plant and what survival to expect, the primary source of toxicity on acid spoils appears to be one of the elements or salts brought into solution by the acidity, rather than the acidity itself. Aluminum and manganese seem to be the most limiting toxic elements.

Berry, Frederick H.

1966. **Diseases.** *In* **Black walnut culture.** U. S. Forest Serv. N. Central Forest Exp. Sta. Walnut Workshop Papers: 88-90, illus.

Describes the diseases that affect black walnut and recommends control measures.

Berry, Frederick H.
1966. **Diseases.** N. Nut Growers Assn. Nutshell 14(1): 10-13.
Describes the diseases that affect black walnut and recommends control measures.

Berry, F. H., and T. W. Bretz.
1966. **Small oak bark beetle a potential vector of oak wilt.** Plant Dis. Rptr. 50: 45-49.
By use of a spermatization technique, adults of the small oak bark beetle *Pseudopityophthorus minutissimus* Zimm. reared from oak wilt-infected materials were found to be carrying the oak wilt fungus *Ceratocystis fagacearum* (Bretz) Hunt. The barkbeetles were found to carry the pathogen both internally and externally. Beetles emerging from a single tree may carry both the A and B compatibility types of the fungus.

Blum, Barton M.
1966. **Snow damage in young northern hardwoods and rapid recovery.** J. Forestry 64: 16-18, illus.
A heavy snow injured at least 50 percent of the stems on a 0.4-acre patch of 7-year-old hardwoods on the Bartlett Experimental Forest. However, 5 years after the damage the area supported a well-stocked stand of promising stems. Young northern hardwoods apparently have the capacity to recover from this apparently severe damage.

Blum, Barton M.
1966. **A new mounting platform for dial-gage dendrometers.** J. Forestry 64: 319-322.
A new type of mounting platform was devised to facilitate use of dial-gage dendrometers on trees as small as 1½ inches in diameter. The new platform, which uses two screw-supports rather than three, compares favorably in accuracy with the standard platforms.

Blum, Barton M., and Dale S. Solomon.
1966. **The accuracy of mean-growth estimates made with dial-gage dendrometers.** U. S. Forest Service Res. Note NE-54, 4 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
Results of a study of radial-growth variation and the accuracy of mean-growth as measured by a dial-gage dendrometer.

Burns, Denver P., and Ralph H. Davidson,
1966. **The amino acids and sugars in honeydew of the tuliptree scale. *Toumeyella liriodendri*, and in the sap of its host, yellow-poplar.** Entomol. Soc. Amer. Annals 59 (6): 1071-1073.
The amino acids and sugars of tuliptree scale *Toumeyella liriodendri* (Gmelin) honeydew and the sap of its host *Liriodendron tulipifera* L. (yellow-poplar) were chromatographically identified. The most abundant sugar in the sap, sucrose, was completely digested by the

scale. This situation has not been previously described for coccids. The results also suggest physiological variation in yellow-poplar.

Campbell, R. W.

1966. **Gypsy moth egg-mass density and subsequent defoliation.** U. S. Forest Serv. Res. Note NE-44, 6 pp. NE. Forest Exp. Sta., Upper Darby, Pa.

From a 20-year record of egg-mass counts and defoliation estimates in central New England, a defoliation frequency matrix was derived and tabulated. Based on five classes of egg-mass density per acre and the trend in egg-mass density from the preceding year, this table provides a useful means of forecasting, within a given risk level, the amount of defoliation to be expected.

Carl, Clayton M. Jr., and Harry W. Yawney.

1966. **Four stratification media equally effective in conditioning sugar maple seed for germination.** Tree Planters' Notes 77: 24-28, illus.

In a study of stratification media, it was found that perlite, sand, sphagnum moss, and germination paper all gave comparable germination of sugar maple seed stratified for 90 days at 33° to 35°F. The germination paper was the most convenient of the four because the seed was readily visible for inspection.

Carlson, Tony C.

1966. **The market for wood pallets in the steel industry.** U. S. Forest Serv. Res. Paper NE-53, 15 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

The structure of the wood pallet market in the steel industry was examined and interviews were conducted in nine of the largest steel corporations. The market is a specialized one in which the place of wood seems assured. It could be expanded by taking advantage of expected growth in production of palletizable steel products, and by replacement of homemade pallets by commercial ones through better sales techniques.

Carpenter, Roswell D.

1966. **Hardwood log and tree grades.** Ky. Governor's Conf. on Forestry 3: 23-30.

The need to measure and predict hardwood timber quality takes on constantly increasing importance. Research in this field supplies hardwood logs and tree grades, the tools that measure quality and predict product yields from a given volume of timber and/or logs.

Champagne, E. Garth.

1966. **Lumber care and handling.** Ky Governor's Conf. on Forestry 3: 55-62.

Emphasizes that sawmill operators should be familiar with the requirements of specific markets. Discusses what operators can do to improve or retain the quality of the lumber after it leaves the headsaw,

and thus increase its value for specific markets. Detailed discussion of air-drying.

Church, Thomas W. Jr.
1966. **The cost of scaling and grading hardwood sawlogs.** U. S. Forest Serv. Res. Paper NE-49, 21 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
Demonstrates that the U. S. Forest Service log-grading system, despite its apparent complexity, can be applied effectively at a cost of as little as 25¢ per 1,000 board feet. The mill yard where logs can be spread out offers the best location for grading. Size of crew and volume of logs handled are important considerations.

Church, Thomas W. Jr.
1966. **Can you afford to grade your hardwood logs?** N. Logger 14 (12): 12-13, illus.
Demonstrates that the U. S. Forest Service log-grading system, despite its apparent complexity, can be applied effectively at a cost of as little as 25¢ per 1,000 board feet. The mill yard where logs can be spread out offers the best location for grading. Size of crew and volume of logs handled are important considerations.

Church, Thomas W. Jr.
1966. **Opportunities for improving the manufacture and serviceability of railroad crossties.** N. Logger 14 (7): 18-19, 38-40, illus.
Discusses the most aggravating problems associated with all phases of the crosstie industry and recommends changes in current production and marketing techniques to alleviate the difficulties. Suggests methods for modernizing both harvesting and manufacture. Describes the advantages of a uniform inspection system properly administered on a nationwide basis.

Church, Thomas W. Jr., and R. M. Godman.
1966. **The formation and development of dormant buds in sugar maple.** Forest Sci. 12: 301-306, illus.
Dormant buds in *Acer saccharum* Marsh. originate at the terminal bud scar and at the bases of lateral shoots. Those formed at the bases of lateral shoots are soon transferred to the main stem and persist for many years after the shoots die and drop off. A minute annual elongation apparently adds one set of bud scales to a dormant bud, so dormant buds are distinguishable from axillary buds by their smaller size at first and by the accumulation of annual elongations during later years.

Church, Thomas W. Jr., and George R. Niskala.
1966. **An elixir for sawmills: cut cants.** N. Logger 14 (10): 18-19, 44, illus.
Illustrates the financial benefits from converting the heart portions of factory-grade logs into industrial timbers rather than low-grade lumber of standard thickness. Cant manufacture permits substantial increases in daily net operating income from savings in saw kerf, in-

creased volume production, and general improvement in overall lumber quality.

Connola, D. P., F. B. Lewis, and J. L. McDonough.
1966. **Experimental field techniques used to evaluate gypsy moth, *Porthetria dispar*, control in New York.** J. Econ. Entomol. 59: 284-287.
Discusses specialized techniques developed in the course of experimental work with *Bacillus thuringiensis* (Bt) and Sevin. These techniques allow assessment of treatments during the larval period and aid in interpreting final evaluations.

Cosenza, B. J., and F. B. Lewis.
1966. **Taxonomic considerations of four "wild"-type crystalliferous bacilli and their toxicity to larvae of the gypsy moth, *Porthetria dispar*.** J. Invert. Path. 8: 520-525.
Four strains of "wild"-type spore-forming crystalliferous bacilli were isolated from dead or diseased gypsy moth larvae during an intensive survey of the microorganisms found in field populations of the gypsy moth. The morphological and physiological characteristics of these strains, together with the Mattes strain of *Bacillus thuringiensis* and an acrystalliferous strain were studied. Results showed that the four crystalliferous bacilli conform to the description of *B. thuringiensis* var. *thuringiensis* Berliner. Serological typing by Madame BeBarjac placed the organisms in serotype I. All crystalliferous isolates were found to be pathogenic. In feeding trials employing 3,900 instar II larvae, significant differences were observed in the toxicity of the laboratory-prepared crystal-spore powders of each wild strain.

Cosenza, B. J., and J. D. Podgwaite.
1966. **A new species of *Proteus* isolated from larvae of the gypsy moth, *Porthetria dispar*** (L.). Antonie van Leeuwenhoek 32: 187-191.
A description of a new species of *Proteus (P. myxofaciens)* that has the unusual ability to form a "slime"-plug in certain media. This ability distinguishes this species from all other species of *Proteus*. Preliminary pathology data are presented.

Cuppett, Donald G.
1966. **Air-drying practices in the central Appalachians.** U. S. Forest Serv. Res. Paper NE-56, 19 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
In a study of commercial air-drying practices at 18 randomly selected sawmill lumber yards in the central Appalachian hardwood region, it was found that degrade losses were within acceptable limits for all sample shipments of yellow-poplar; but losses in half the sample red oak shipments were excessive. The chief types of defects in red oak were checks and splits; and in yellow-poplar, stain and warp. Recommends seven ways for improving air-drying practices to reduce losses.

Czapowskyj, Miroslaw M., and William E. McQuilkin.
1966. **Survival and early growth of planted forest trees on strip-**

mine spoils in the anthracite region. U. S. Forest Serv. Res Paper NE-46, 29 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

Many trees have been planted on strip-mine spoils in the Anthracite Region, but their performance on these sites had not been evaluated. A survey of existing plantations revealed that most species survive adequately on all four types of strip-mine spoil. Height growth on spoils was generally comparable to growth on natural soils. Overall performance indicates that tree cover of some sort can be re-established on practically all anthracite strip-mine spoils.

Davis, Grant.

1966. **The cooperative research program in Pennsylvania.** *In* Pa. State Univ. Coal Mine Spoil Reclamation Symp. Proc. 1965: 55-61.

Describes the formation of the Research Committee on Coal Mine Spoil Revegetation in Pennsylvania and provides a review of the research conducted under the committee's sponsorship. Results of past studies are summarized and examples are given to show how these research findings have been put to practical use in the revegetation of Pennsylvania mine spoils.

DeBald, Paul S., and David A. Gansner.

1966. **Kentucky forests: Eastern Unit.** U. S. Forest Serv. Resource Bull. CS-4. 34 pp., illus.

One of seven reports presenting and analyzing results of the second comprehensive forest inventory of Kentucky. One-third, or 1.9 million acres, of the Western Coal Unit is forested. The current annual harvest of timber is greater here than in any other survey unit in Kentucky. Lumber production averages more than 1 million board feet per mill. Nearly three times as much pole timber could be harvested annually from the region.

Dempsey, Gilbert P.

1966. **A review of forest-based cooperatives.** *In* Forest Cooperatives—USDA Workshop Proc.: 49-62. USDA Misc. Unnumbered Pub., 96 pp., illus.

Explains why some 68 forest cooperatives were established, what their problems were, and why most of them went out of business. Prime reasons for discontinuance were: an inadequate volume of business, lack of interest and subsequent support by members, management problems, and lack of capital.

Dodd, Steven J.

1966. **Utilization of conveyors in the wood industry.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 100-103, illus.

A general discussion of the advantages and disadvantages of the overland belt and mechanical conveying devices in the Appalachian area for the transportation of wood.

Donley, D. E., and D. P. Burns.

1966. **Dispersal of the tuliptree scale.** (Abstr.) Ecol. Soc. Amer. Bull. 47: 153.

Dispersal of the tuliptree scale *Toumeyella liriodendri* (Gmelin) is discussed as it relates to the life cycle and mortality rate of the scale. The sampling and trapping methods used to study scale dispersal are described, and results are given.

Doolittle, Warren T.
1966. **Some implications of even-aged management in the production of Appalachian hardwoods.** Forest Prod. J. 16: 25-28, illus.
Describes the advantages of even-aged management for the production of high-quality hardwoods in the Appalachian Region. However, uneven-aged management is still appropriate under certain conditions. Foresters and land managers are urged to utilize their technical knowledge to select the best management system for each set of circumstances.

Ellefson, Paul V.
1966. **Our maladjusted crosstie market: what's ahead?** Progr. Railroading 9 (6): 45-49.
The railroad's demand for wooden ties is increasing faster than the available supply. This is not a short-term condition, and future crosstie demands will be even greater. This condition can be corrected by a change in the purchasing policy of many railroads and by an adjustment in the manufacturing techniques of the producers.

Ellefson, Paul V.
1966. **Marketing research at the Forest Products Marketing Laboratory.** Amer. Christmas Tree J. (10(4): 16.
To be of greatest value to the Christmas tree industry, Christmas tree marketing research at the Forest Products Marketing Laboratory will include the analysis of current marketing methods and the development of information leading to more efficient marketing. Opportunities for expanding the growing and marketing of Christmas trees and measures for improving the competitive position of the natural tree will be investigated also.

Escher, A. R., and D. R. Satterlund.
1966. **Forest protection and streamflow from an Adirondack watershed.** Water Resources Res. 2 (4): 765-783.
On the Sacandaga River watershed above Hope, N. Y., a slow one-directional change in land use and an increase in forest cover have been correlated with a decrease in average annual, dormant season, and April runoff over the 39-year period 1912-50. In 1912 forest cover was probably as low as it had ever been after widespread logging, insect attacks, and a series of fires. As the beaver population increased explosively and forest density increased, the average annual streamflow decreased 7.72 inches, mainly as a result of a 5.18-inch decrease in dormant season runoff.

Federer, C. A., and C. B. Tanner.
1966. **Spectral distribution of light in the forest.** Ecol. 47: 555-560.
Differences in spectral distribution of shade light were found between

hardwoods and softwoods, and between clear and cloudy days. An energy maximum at 550 nm, a minimum at 670 to 680 nm, and a very high maximum in the near-infrared occurred under all species. Four components of light within a plant canopy are distinguished and discussed.

Federer, C. A., and C. B. Tanner.
1966. **Sensors for measuring light available for photosynthesis.** Ecol. 47: 654-657.
Consideration of energy absorption by photosynthesis indicates that photon flux density in the 400- to 700-nm wavelength range is the best measure of light available for photosynthesis. When light spectral distribution changes, deviation of sensor spectral response from the photon response introduces errors in measurements. A selenium photovoltaic cell with a Wratten 85C filter is a simple system that closely approximates the photon response.

Frayer, Warren E.
1966. **Weighted regression in successive forest inventories.** Forest Sci. 12: 464-472.
An analysis of available data to test the validity of updating timber volume estimated by means of least-square regression. Using Ware's model, analysis indicated that all assumptions were justified except homogeneity of the variance. Weighted regression — employing a function of the expected current volumes as a weight — stabilized the variance. The results suggest widespread applicability of the weighting procedure for estimating variances efficiently.

Frayer, Warren E., and Joseph E. Barnard.
1966. **Average growth rates in southern Maine.** U. S. Forest Serv. Res. Note NE-47, 8 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
The purpose of the study was to obtain average net growth rates in gross cubic-foot volume for 24 stand classifications consisting of four species groups, three height classes, and two density classes. A landowner who used these classifications could arrive at an average growth rate for his tract. The variances given in the report for the stand classifications enable calculation of sampling error as a measure of reliability.

Gabriel, William J.
1966. **The onset and duration of stigma receptivity in sugar maple flowers.** Forest Sci. 12: 14-18.
Sugar maple pollen germination and pollen-tube growth were measured at various stages of stigma development in order to determine the optimum stage of stigma receptivity. The appearance of the female flower is described at each of these stages, thus facilitating controlled pollination with this species.

Gambrell, S. C. Jr., and E. F. Byars.
1966. **Cutting characteristics of chain saw teeth.** Forest Prod. J. 16 (1): 62-71, illus.

An investigation of the mechanics of cutting wood with chain saw teeth. The three principal cutting forces increased appreciably with increased depth of cut and decreased slightly with increased cutting speed.

Gansner, David A.
1966. **Timber resources of Missouri's Southwestern Ozarks.** Univ. Mo. Agr. Exp. Sta. and U. S. Forest Serv. 51 pp., illus.
One of five regional reports presenting and analyzing results of the second comprehensive forest inventory of Missouri (1959). Presents statistical findings on forest-land area, timber volume, and growth in the Southwestern Ozark Region. Reports a decline in the supply of high-quality timber and the need for better management of the timber resource.

Gansner, David A.
1966. **Timber resources of Missouri's Northwestern Ozarks.** Univ. Mo. Agr. Exp. Sta. and U. S. Forest Serv. 51 pp., illus.
Last of five regional reports presenting and analyzing results of the second comprehensive forest inventory of Missouri (1959). A report on the findings of the Forest Survey in the Northwestern Ozark Region, presenting statistical findings on forest-land area, timber volume, and growth. Statistical data needed in long-range planning to meet future timber demands are presented.

Gansner, David A., and Paul S. DeBald.
1966. **Kentucky forests: Northern Cumberland Unit.** U. S. Forest Serv. Resource Bull. CS-5. 37 pp., illus.
One of seven unit reports presenting and analyzing results of the second comprehensive forest inventory of Kentucky (1963). Presents statistical findings on forest-land area, timber volume, and growth in the Northern Cumberland Unit of Kentucky.

Gansner, David A., and Paul S. DeBald.
1966. **Timber resources of Kentucky: Pennyroyal Unit.** U. S. Forest Serv. Resource Bull. CS-6. 46 pp., illus.
One of seven unit reports presenting and analyzing results of the second comprehensive forest inventory of Kentucky (1963). Presents statistical findings on forest-land area, timber volume, and growth in the Pennyroyal Unit of Kentucky. Forest area has increased, but merchantable timber volume has decreased since the last survey in 1949.

Gansner, David A., and Paul S. DeBald.
1966. **Timber resources of Kentucky: Bluegrass Unit.** U. S. Forest Serv. Resource Bull. CS-7. 33 pp., illus.
One of seven unit reports presenting and analyzing results of the second comprehensive inventory of Kentucky (1963). Presents statistical findings on forest-land area, timber volume, and growth in the Bluegrass Unit of Kentucky. Reports a decline in forest acreage and timber volume since the last survey in 1947.

Gansner, David A., and Paul S. DeBald.
1966. **Timber resources of Kentucky: Western Unit.** U. S. Forest Serv. Resource Bull. CS-8. 34 pp., illus.
One of seven unit reports presenting and analyzing results of the second comprehensive forest inventory of Kentucky (1963). Presents statistical findings on forest-land area, timber volume, and growth in the Western Unit of Kentucky. Reports an increase in the volume of timber and an excess of growth in large diameter classes.

Gansner, David A., and Burton L. Essex.
1966. **Timber resources of Missouri's riverborder region.** Univ. Mo. Agr. Exp. Sta. and U. S. Forest Serv. 73 pp., illus.
One of five regional reports presenting and analyzing reports of the second comprehensive forest inventory of Missouri (1959). Forest area declined since the initial forest inventory of 1947, but the volume of growing stock increased by 15 percent. Most of this gain was in small timber. The volume of high-quality stock declined and current statistics indicate this trend is continuing.

Gerhold, H. D., E. J. Schreiner, R. E. McDermott, and J. A. Winieski.
1966. **Breeding pest-resistant trees.** 505 pp., illus. Pergamon Press, Oxford, England.
Proceedings of a NATO and National Science Foundation advanced study institute on genetic improvement for disease and insect resistance of forest trees, held at The Pennsylvania State University, University Park, Pa.

Gibson, Harry G.
1966. **New developments in transmissions, engines, and brakes for logging machines.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 5-14, illus.
Component parts of machines are analyzed. New developments, not now on the market as logging machinery components, are discussed. Limitations and advantages are given for hydrostatic and hydrokinetic drive systems. Performance of various types of brakes are analyzed. Probable life of gears is discussed, and a table of comparative characteristics is given for gasoline and diesel engines.

Gibson, Harry G., and Robert L. Hartman.
1966. **Selecting a wheel skidder for Appalachian logging.** S. Lumberman 213 (2656): 195-198, illus.
Analyses are given on: (1) The effects of weight, (2) articulation features, (3) controls arrangement and operator reaction, (4) factors affecting speed, (5) log fenders on a skidder, (6) relative performance of solid-drive and hydrokinetic transmissions, (7) engine requirements, (8) tire requirements, and (9) winch variations and performance. Terrain factors are included in this analysis.

Gregory, Garold F.
1966. **An apparatus for obtaining fluid from xylem vessels.** Phytopathol. 56: 463, illus.

The design of an apparatus that can be used to displace xylem fluid is illustrated and its operation is explained.

Hagenstein, Perry R.

1966. **Projecting regional timber-products production.** Soc. Amer. Foresters Proc. 1965: 92-94, illus.

Discusses some of the problems in making regional analyses; identifies some reasonable objectives on which an analysis of timber-products production could be based; and describes one approach that might be useful in projecting regional timber-products production.

Hajny, George J., Richard N. Jorgensen, and James J. Ferrigan.

1966. **Outside storage of hardwood chips in the Northeast. I. Physical and chemical effects.** U. S. Forest Prod. Lab. mimeo. 30 pp., illus.

Discusses the physical and chemical effects of outside storage on hardwood chips. The increased surface area of chips results in chemical changes that cause a rise in temperature and a discoloration of the chips. In a chip pile of northeastern hardwoods, loss of wood substance amounted to about 6 percent after 6 months of storage. Discoloration of chips and loss of pulp yield were apparent after only 1 month of storage in the chip pile.

Harper, D. O., and H. P. Simons.

1966. **Explosives, propellants, and exotic fuels for forestry operations.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 95-99.

Properties of fuels are described. Total energy available and the rate of energy release in controlled situations is discussed along with fuel modifications to get variations of performance. Parameters used for fuels in rockets, monopropellants, and bipropellants are described. Limitations of both solid and liquid fuels are discussed.

Hart, A. C.

1966. **Research programs of Northeastern Forest Experiment Station.** Amer. Pulpwood Assn. Tech. Papers Jan. 1966: 23-25.

Describes the Northeastern Station's silvicultural research program in the spruce-fir region. A brief description of past research, plus a detailed account of studies now under way at the spruce-fir silviculture project located at Orono, Maine.

Hart, George

1966. **Forest cutting to increase streamflow in the White Mountains.** N. H. Forest Notes 89: 6-9.

Points out the problem of seasonal flow distribution on undisturbed forest land and describes the research program under way to solve this problem. A recently completed clearcutting experiment on the Hubbard Brook Experimental Forest is described.

Hartman, Robert L.

1966. **Selecting and training logging machine operators.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 91-94.

Shows that harvesting machines are being unnecessarily abused because of the inadequacy of the operators. Describes physical and psychological characteristics that are desirable for a perspective skidder operator. Outlines a program for training the skidder operator in fundamentals such as safety features.

Hay, C. John, and David E. Donley.
1966. **Insect pests.** *In* Black walnut culture. U. S. Forest Serv. N. Central Forest Exp. Sta. Walnut Workshop Papers: 83-87, illus.
Discusses the important insect enemies of black walnut and butternut in the eastern United States and Canada — defoliators, sucking insects, and nut borers. Biology, descriptions, damage, and control are included for each insect pest.

Hay, C. John, and David E. Donley.
1966. **Insect pests.** N. Nut Growers Assn. Nutshell 14(1): 14-17.
Discusses the important insect enemies of black walnut and butternut in the eastern United States and Canada — defoliators, sucking insects, and nut borers. Biology, descriptions, damage, and control are included for each insect pest.

Holland, I. I., E. Kallio, and K. L. Quigley.
1966. **Prospects for hardwood pulp manufacture in Illinois.** Univ. Ill. Agr. Exp. Sta. Bull. 718, 83 pp., illus.
The timber resources of Illinois make only a token contribution to the State's income. However, there is the potential for a much larger contribution. Illinois has a substantial surplus of low-quality timber suitable for pulpwood, an excellent transportation system, adequate labor and power facilities, and promising sites for new pulp mills.

Hopkins, W. S., and W. F. LaPage.
1966. **The future of forest recreation lands.** Sixth World Forestry Congress Proc. Madrid, Spain.
A socio-political analysis of current trends in outdoor recreation, and their probable implications for future policies and programs in public recreation management and planning. Emphasis is placed on some of the likely results of increased private activity, the growing specialization of recreation interests, and the ever-increasing number of recreational organizations and clubs.

Houston, David R.
1966. **Strumella canker of oaks.** U. S. Dep. Agr. Forest Pest Leafl. 101, 8 pp., illus.
Describes and illustrates the symptoms of this important canker disease of oaks. Also includes descriptions of the imperfect *(Strumella coryneoidea)* and perfect *(Urnula craterium)* stages of the causal fungus, and suggestions for control.

Hoyle, Merrill C.
1966. **Diameter growth of yellow brich not closely related to density.** J. Forestry 64: 628-629, illus.

Curves illustrate in the initiation, duration, and rates of diameter increment among dominant and codominant yellow birch growing on a poorly-drained podzol soil. Annual diameter increment of these trees did not seem to be related to either tree size or stand density, suggesting that factors other than density may be limiting to yellow birch growth on these soils.

Hoyle, Merrill C.
1966. **Forest soils in the White Mountains: a look at the forest floor.** N. H. Forest Notes 90: 3-9, illus.
General description of the forest floor in the White Mountains of New Hampshire, including decay processes and organisms involved and the importance of organic layers to forest trees.

Jensen, K. F.
1966. **A portable gas analyzer.** Forest Prod. J. 16: 38-39, illus.
A portable gas analyzer is described that can measure oxygen and carbon dioxide concentrations in small gas samples.

Jorgensen, R. N., and H. O. Fleischer.
1966. **Government wood scientists and technologists.** Soc. Wood Sci. and Technol. Log, August 1966: 2-5.
A discussion of the Government's need for wood scientists and technologists. Discusses a proposed revision of the Civil Service qualification standard for education and position adaptability. Spells out the Government's need for 60 percent of all university graduates in this field over the next 5 years. Points out the need for more extensive information dissemination to high school prospects and more active recruiting at the colleges.

Kingsley, Neal P.
1966. **Pulpwood production in the Northeast — 1963.** U. S. Forest Serv. Resource Bull. NE-3, 26 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
First in a series of annual publications, this report contains data on the production of round pulpwood by counties in the 12 Northeastern States and the production of pulpwood chips and miscellaneous wood-industry byproducts used in the manufacture of woodpulp in each of the 12 states. Also data that show the trend in woodpulp consumption in the Northeast from 1955 through 1963.

Klein, William H., and Franklin B. Lewis.
1966. **Experimental spraying with *Bacillus thuringiensis* for control of the spruce budworm.** J. Forestry 64: 458-462, illus.
Experimental results of helicopter spraying of *Bt* against spruce budworm. Effectiveness was not satisfactory for control. Carry-over of *Bt* into pupae was noted.

Koelling, Melvin R., and William J. Gabriel.
1966. **Selection and propagation of superior sugar maple trees.** Nat. Maple Syrup Dig. 5 (2): 6-8.

Describes the research program on selection and breeding of sugar maple at the Northeastern Forest Experiment Station in Burlington, Vermont. The objective of the research is to develop trees with higher sugar content in the sap, and/or trees that produce greater total sap volume.

LaPage, Wilbur F.

1966. **Success of campgrounds studied as guide to recreation planning.** U. S. Forest Serv. Res. Note NE-43, 7 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

Discusses the effects of enterprise age, attraction, size, location, and investment, on the attendance at 85 private campgrounds in New Hampshire, during the 1963 camping season. Defines enterprise success as a minimum occupancy of 50 percent of capacity throughout the summer season, and discloses that, of the 85 enterprises, only 37 realized a successful level of occupancy.

Lazarus, H., W. Tegeler, H. M. Mazzone, J. C. Leroy, B. A. Boone, and G. E. Foley.

1966. **Determination of sensitivity of individual biopsy specimens to potential inhibiting agents: Evaluation of some explant culture methods as assay systems.** Cancer Chemotherapy Repts. 50: 543-555.

Tissue explants, normal or carcinogenic in origin, were studied in a number of explant systems in an attempt to develop a culture method suitable for the evaluation of anti-tumor agents. The results indicated that, of the explant methods considered, a modification of the chick mesonephron method and a microculture coverslip method were of most interest with respect to predictability and reliability of growth aspects of replicate explants of individual tissue specimens.

Leak, William B.

1966. **Analysis of multiple systematic remeasurements.** Forest Sci. 12: 69-73.

Multiple remeasurement data has often been analyzed by regression techniques, ignoring the fact that 10 observations on each of 5 trees are not either conceptually or statistically equivalent to 50 separate observations. An analytical method for remeasurement data is proposed, based upon the assumption that each experimental unit provides an independent estimate of the elevation and slope of the population regression line.

Lewis, Franklin B., and Donald P. Connola.

1966. **Field and laboratory investigations of *Bacillus thuringiensis* as a control agent for gypsy moth, *Porthetria dispar* (L.).** U. S. Forest Serv. Res. Paper NE-50, 38 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

The results of 3 years field testing of *Bt* against gypsy moth. Presents problems encountered and solutions arrived at. Gives data on effects of stabilizers and adjuvants on viability of micro-organism; and data on gut pH, effect of *Bt* on feeding activity of larvae, and antibiotic effect of major host trees in infested area.

Little, S.

1966. **Mistblower application of herbicides in multiple-use forestry.** NE. Weed Contr. Conf. Proc. 20 (Supplement) 4 pp.

A summary discussion illustrating the wide use of mistblown herbicides in intensive multiple-use forestry. For timber production, mistblowing is used in the selective release of conifers, in preparing areas for desirable reproduction, or in preparing areas for direct seeding. It is also being used to improve water supply or quality in municipal watershed and might be used to favor herbaceous plants for game or to create park-like stands for recreation.

Little, Silas, and François Mergen.

1966. **External and internal changes associated with basal-crook formation in pitch and shortleaf pines.** Forest Sci. 12: 268-275, illus.

Successive sketches show changes in basal form of 10 pitch pine and 22 shortleaf pine seedlings through their first 6 years, or until the seedlings died. Only 2 of the 21 seedlings surviving 6 years did not form a typical basal crook. Changes in stem form can be explained on the basis of (1) weak stems, (2) usually upright direction of apical growth, and (3) formation of compression wood and eccentric growth rings.

Longhouse, A. D., and K. C. Elliott.

1966. **Research in power sources as preliminary to new concepts of wood tools.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 104-113, illus.

Discusses the various types of power sources and the possibilities of adapting them to logging tools, including fuel cells, air motors, small turbines, free-piston engines, and electric motors.

Lull, Howard W.

1966. **An annotated bibliography of watershed management research by the Northeastern Forest Experiment Station, 1931-65.** U. S. Forest Serv. Res. Paper NE-48, 36 pp. NE. Forest Exp. Sta., Upper Darby, Pa.

Annotated citations of 156 publications on watershed management by the Northeastern Station. There is also a brief review and assessment of research accomplishments to date.

Lull, Howard W., and Kenneth G. Reinhart.

1966. **Implications of even-aged management on water.** *In* Trends from selection cutting to even-aged management. Soc. Amer. Foresters Proc. Allegheny Sect. 1965: 54-61.

The effects of various cutting methods on water yield are described. Timber cutting under the uneven-aged system would have a negligible effect. It is estimated that even-aged management would increase yater yield slightly, would increase low flows only a little more, would have a minor effect on peak flows, and would not necessarily reduce water quality.

Lull, Howard W., and William E. Sopper.
1966. **Factors that influence streamflow in the Northeast.** Amer. Geophys. Union Water Resources Res. 2: 371-379, illus.
Streamflow at selected flow durations of 137 watersheds in the Northeast were related to selected climatic, topographic, and land-use variables. The most influential variables on annual and seasonal discharges, in descending order, were precipitation, percentage of watershed area in forest cover, elevation, latitude, July mean maximum temperature, and percentage of swamp.

Lull, Howard M., and William E. Sopper.
1966. **How harvesting forest products affects water yield in Appalachia.** Soc. Amer. Foresters Proc. 1965: 108-112, illus.
Differences in monthly precipitation and potential evapotranspiration at six stations in Appalachia from Harrisburg, Pa., to Birmingham, Ala., were related to the influence of windward and leeward locations, elevation, and latitude. Increases in annual water yield from clearcuttings at Fernow and Coweeta were approximated from an estimated actual transpiration. Estimated annual transpiration at the 6 locations, ranging from 11 to 16 inches, suggests that increases in water yield may be achieved by clearcutting.

Manthy, Robert S.
1966. **Economic-base projections for river-basin planners.** Soc. Amer. Foresters Proc. 1965: 94-97.
Discusses four methods used to project industrial activity in river basins in the Northeast. The closed dynamic simulation model appears to be the most attractive analytical technique discussed.

Manthy, Robert S.
1966. **A forest economist's view of pulpwood marketing systems.** Amer. Pulpwood Assn. Tech. Papers Jan. 1966: 5, 6, 8.
Discusses differences between "procurement" as viewed by the pulpwood businessman and the broader concept "marketing" which is concerned with all the activities that must take place to move goods from a producer to a consumer. Shows how knowledge of the marketing system can help the pulpwood procurement man to understand technical, economic, social, and psychic forces likely to affect future supply conditions.

Marquis, David A.
1966. **Germination and growth of paper birch and yellow birch in simulated strip cuttings.** U. S. Forest Serv. Res. Paper NE-54, 19 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
Germination, survival, and growth of paper birch and yellow birch were studied under saran cloth shade screens that simulated various types of forest openings. Best conditions were found under screens that represented very narrow east-west and north-south strip cuttings. Full sunlight produced lowest germination and survival.

Marty, Robert
1966. **Economic guides for blister-rust control in the East.** U. S.

Forest Serv. Res. Paper NE-45, 14 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

Provides an objective basis for evaluating opportunities for blister rust control in white pine stands of the eastern United States. The evaluation procedures lead to an estimate of the value saved by instituting an immediate control treatment rather than postponing treatment 10 years. Immediate control is economically justified when present worth of value saved exceeds the cost of control.

Marty, Robert J.

1966. **How much can you afford to spend controlling forest insects?** La. State Univ. Forestry Proc.: 38-50, illus.

Discusses ways to evaluate insect-control procedures including development of control-cost and value-saved schedules. This evaluation is a tool for deciding a course of action when a choice must be made among several control projects or other investment possibilities.

Marty, Robert, Charles Rindt, and John Fedkiw.

1966. **A guide for evaluating reforestation and stand improvement projects in timber management planning on the national forests.** U. S. Dep. Agr. Handbook 304. 24 pp.

Describes a procedure for economic evaluation of reforestation and timber stand improvement projects, and indicates a method for scheduling available funds to projects that will yield the highest rates of financial return. Economic evaluation of projects shows that inefficiencies and resultant higher costs reduce the economic justification for projects.

May, Robert F., and William A. Berg

1966. **Overburden and bank acidity — eastern Kentucky strip mines.** Coal Age 71(6): 74-15, illus.

Acidity determinations were made on highwalls and the associated contour strip-mine banks of five major coal seams in eastern Kentucky. Results showed that about half the spoils but only a tenth of the highwall strata had acidity of pH 4.0 or below. Extremely acid bone or rider coal spread over the surface of the banks account for the majority of the acidity. Knowledge of the geology and proper handling of acid-bearing material during the mining operation can materially limit their adverse effects.

McQuilkin, William E.

1966. **Reclamation for aesthetics.** *In* Pa. State Univ. Coal Mine Spoil Reclamation Symp. Proc. 1965: 97-105.

Natural beauty—or quality of environment—has become an important concern of government, industry and people in all walks of life. Aesthetic improvement of mine spoils has been given substantial impetus by this newly launched national campaign for natural beauty. Local community groups can do much toward aesthetic improvement on their own if they have the necessary desire and determined leadership. An outstanding example of the accomplishments of the one community action program the Anthracite region is cited.

Mook, Paul V.

1966. **Heart rots of balsam fir.** U. S. Dep. Agr. Forest Pest Leafl. 100, 6 pp., illus.

Describes the important decays of balsam fire and discusses the relative importance of the fungi inciting them. Data are presented that describe the frequency of occurrence of the fungi, and the location and extent of the associated decays. General recommendations are made for the utilization and management of balsam fir.

Mott, D. G.

1966. **The analysis of determination in population systems.** *In* Systems Analysis in Ecology, edited by K. E. F. Watt: 179-194. Academic Press, New York.

The importance of joint variation among the "independent" variables in determining variation in a dependent variable is shown, and a procedure of analyzing this component statistically by use of the covariance terms in a multiple regression is demonstrated. An application to the analysis of life-table data of the gypsy moth is cited.

Nagle, George S., and Robert S. Manthy.

1966. **The market for fireplace wood is an urban area of Connecticut.** U. S. Forest Serv. Res. Paper NE-51, 16 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

Describes the market for fireplace wood, now Connecticut's most important primary timber product, in the New Haven area. Emphasis is placed on sources of supply and marketing practices.

Niskala, George R., and Thomas W. Church Jr.

1966. **Cutting hardwood cants can boost sawmill profits.** U. S. Forest Serv. Res. Note NE-46, 7 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

Illustrates the financial benefits from converting the heart portions of factory-grade logs into industrial timbers rather than sawing the hearts into low-grade lumber of standard thickness. Cant manufacture permits substantial increases in daily net operating income from savings in saw kerf, increased volume production, and the general improvement in overall lumber quality.

Northeastern Forest Experiment Station.

1966. **Report 1965.** NE. Forest Exp. Sta. 70 pp., illus. Upper Darby, Pa.

A summary of research activities and accomplishments in timber management, forest insects and diseases, forest economics, watershed management, forest utilization, forest recreation, wildlife habitat, and forest products marketing. Annotated list of publications.

O'Dell, T. M., and W. D. Rollinson.

1966. **A technique for rearing the gypsy moth *Porthetria dispar* (L.) on an artificial diet.** J. Econ. Entomol. 59: 741-742.

A synthetic diet and a method of handling the developmental stages of the insect to obtain maximum growth and survival are described.

Parker, Homer W.
1966. **Rubber-tired skidders — training needs.** N. Logger 14(11): 16, 39, illus.
Operator ability is stressed for the efficient performance of a wheeled skidder. The most important items of skidder operation are outlined with brief comments on what should be observed and mastered by the operator. Minimum maintenance practices are also given.

Parker, Homer W.
1966. **Human engineering aspects of machine selection and utilization.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 25-29, illus.
Describes the effect of vehicle design on the operator's efficiency and comfort. Suggests dimensions of machines and their parts that will improve the efficient performance of both machine and operator.

Parker, Homer W.
1966. **Selection and use of forest machines.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 50-55, illus.
Outlines economic considerations that should influence the purchase of equipment. Discusses the soil-vehicle relationship and the performance of different vehicles in different soil conditions. The features and limitations of component parts of machines are considered, and the importance of available service is emphasized.

Parker, Homer W.
1966. **Some cableway systems applicable to Appalachia.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 73-79, illus.
Evaluates factors affecting the profitable operation of various cableway systems. Single-span skyline cable systems have extremely limited possibilities in Appalachia, but economically feasible units could be developed. Describes improved designs that possibly will be effective in Appalachian areas.

Parker, Homer W.
1966. **Balloon logging.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 85-90, illus.
Describes balloon logging and gives specifications for balloons used in logging. Outlines advantages and disadvantages of the system. Lists areas in which additional research on balloon logging is needed.

Parker, Homer W.
1966. **New U. S. Forest Service unit applies engineering research to Appalachian logging.** N. Logger 14(10): 16, 57, illus.
Possibilities of improvement and changes in logging methods resulting from engineering research are summarized. New Forest Service facilities are described. Some of the approaches and concepts used by engineering researchers are discussed.

Phillips, John J.
1966. **Site index of yellow-poplar related to soil and topography in**

southern New Jersey. U. S. Forest Serv. Res. Paper NE-52, 10 pp. NE. Forest Exp. Sta., Upper Darby, Pa.

Depth to mottling, depth to tight subsoil, clay content of the subsoil, topographic position, and surface soil drainage were all related to yellow-poplar site index in the New Jersey Coastal Plain. The resulting regression equation explains about 67 percent of the observed variation in site index.

Phillips, John J.

1966. **Site index of Delaware-Maryland sweetgum stands in relation to soil characteristics.** U. S. Forest Serv. Res. Note NE-48, 5 pp. NE. Forest Exp. Sta., Upper Darby, Pa.

Fine sand, silt, and clay contents of the B_2 horizon, depth to a tight B_2 horizon, and tree age where all related to sweetgum height in Delaware and Maryland. The resulting regression equation explained 75 percent of the observed variation; 45 percent was due to tree age. Differences between this and a previously-reported equation for New Jersey soils are discussed.

Phillips, Ross A.

1966. **Loading machines.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 114-122, illus.

Discusses log-loading, its effects on harvesting operations, and compares log-loading with rates of loading similar material in industry. Describes different types of loaders and discusses factors to be considered in selection of a loader.

Phillips, Ross A., and Richard A. Spray.

1966. **Wheeler skidder performance.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 39-49, illus.

Analyzes the factors that affect the performance of wheeled skidders and gives a theoretical concept of what can be expected of wheeled skidders under certain conditions.

Plass, William T.

1966. **Land disturbances from strip-mining in eastern Kentucky. I. Upper Cumberland coal reserve district.** U. S. Forest Res. Note NE-52, 7 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

First of six reports providing an estimate of the acreage disturbed by mining and by the associated coal-haul roads in eastern Kentucky.

Podgwaite, John D., and Benjamin J. Cosenza.

1966. **Bacteria of living and dead larvae of *Porthetria dispar* (L.).** U. S. Forest Serv. Res. Note NE-50, 7 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

A preliminary study of the bacteria associated with living and dead larvae of the gypsy moth *(Porthetria dispar* (L.)).

Quigley, Kenneth L., and Ronald D. Lindmark.

1966. **Timber resources.** *In* Black walnut culture. U. S. Forest Sev.

N. Central Forest Exp. Sta. Walnut Workshop Papers: 6-12, illus.

Discusses present black walnut timber resources and the outlook for demand and supplies of walnut timber. The annual cut of high-quality walnut logs exceeds the annual increase in quality material. The outlook for high-quality walnut timber in sufficient quantity to supply current and increasing levels of demand is not promising.

Reigner, Irvin C.

1966. **A method of estimating streamflow loss by evapotranspiration from the riparian zone.** Forest Sci. 12: 130-139, illus.

Conservative values of daily streamflow loss by evapotranspiration from the riparian zone, obtained by analysis of hydrographs of the Dilldown Watershed in Pennsylvania, were related to mean daily streamflow and vapor-pressure deficit. The prediction equation accounted for 76 percent of the observed variation in daily loss.

Reinhart, K. G.

1965. **Thirteen million pounds.** Va. Forests 20: 9-10.

On the Fernow Experimental Forest in West Virginia, each acre receives an average of 13 million pounds of precipitation each year. The forest serves to protect the soil from this heavy bombardment; it maintains infiltration of water into the soil and reduces erosion. Research on the Fernow forest is described and the effect of various forest treatments on water resources are discussed.

Rexrode, Charles O., and Arthur C. Lincoln.

1965. **Distribution of oak wilt.** Plant Dis. Rptr. 49: 1007-1010, illus.

This fungus disease has caused serious losses among oaks of the red oak group, and today still presents a threat of potential destruction to all oak species growing in the 20 states where its presence is recognized. The fungus is or has been found in 616 counties in 20 states.

Roach, Benjamin A.

1966. **Is even-aged management practical for small woodlands in the Central States?** Soc. Amer. Foresters Proc. 1965: 151-154, illus.

Discusses the effect of property size on the applicability of various types of forest management. If cutting intervals are based on a realistic estimate of growth over an entire rotation cutting intervals for even-aged and uneven-aged management will be similar. Thus the property size will determine whether or not *any* sustained-yield management is feasible, but on any given property, sustained-yield even-aged management will be just as practical as uneven-aged management.

Sander, Ivan L.

1966. **Natural reproduction.** *In* Black walnut culture. U. S. Forest Serv. N. Central Forest Exp., Sta. Walnut Workshop Papers: 18-19.

Clearcutting appears to be the best method to use in reproducing black walnut naturally. More walnut seedlings were found after clearcutting than after either selection or shelterwood cutting, and growth

rate was also best after clearcutting. Because many walnuts are removed or destroyed by nut collectors and rodents, it may be that walnut seedlings become established in quantity only after a good nut year.

Santamour, Frank S. Jr., and Arnold D. Rhodes.
1966. **A trial of pales weevil resistance.** Tree Planters' Notes 76: 21-23.
Describes a study to determine the relative susceptibility of various white pine species, hybrids, and provenances to the pales weevil. The best possibility for selection of white pines resistant to pales weevil for any particular area would appear to be in the testing of various provenances of *Pinus strobus*.

Sarles, R. L.
1966. **Study shows lumber preferences of three user groups.** Wood and Wood Prod. 71(8): 39, 40, illus.
Gives hardwood lumber specifications for the flooring, pallet, and furniture industries. Flooring and pallet makers would pay a higher price for lumber cut to their specifications, but furniture manufacturers are satisfied with hardwood timber as it is now manufactured and marketed.

Sarles, R. L.
1966. **A marketing opportunity for producers of hardwood lumber—tailor production to fit customers' needs.** S. Lumberman 212 (2642): 12, 14, 16.
Recommends the hardwood sawmill industry become customer-oriented. Gives lumber specifications for the hardwood sawmill industry to follow in supplying lumber to pallet, flooring, and furniture industries. Recommends steps producers can take in beginning a customer-oriented program.

Schmidt, Robert A.
1966. **Temperature and atmospheric moisture regimes in the pine stump habitat of *Fomes annosus*.** (Abstr.) Phytopathol. 56: 899.
Temperature and relative humidity regimes in the stump habitat of *Fomes annosus* were studied in a pine plantation in Pennsylvania. The results of these studies indicate clearly that field experiments relating fungus activity to temperature or relative humidity must consider the micro-environment in the biotope of the fungus.

Schreiner, Ernst J.
1966. **Future needs for maximum progress in genetic improvement of disease resistance in forest trees.** *In* Breeding pest-resistant trees. NATO and NSF Symp. Proc.: 455-466.
Discusses the need for interdisciplinary research for maximum genetic improvement in forest trees, and suggests the development of synthetic multiclonal hybrid varieties. Such varieties would be mixtures of many hybrid clones resistant to one or more pests and sufficiently similar in their growth habits to be grown in random mixture. Multi-

clonal hybrid varieties would permit early utilization of the best genotypes and continuous flexibility of the clonal mixtures to meet changing conditions.

Schreiner, Ernst J.
1966. **Maximum genetic improvement of forest trees through synthetic multiclonal hybrid varieties.** NE. Forest Tree Impr. Conf. Proc. 13: 7-13, illus.
Suggests the development of synthetic multiclonal hybrid varieties — mixtures of many genetically superior hybrid clones sufficiently similar in their growth requirements to be grown in random mixtures. The advantages of such mixtures are described, and the need for basic research on vegetative propagation is stressed.

Seliskar, Carl E.
1966. **Virus and viruslike disorders of forest trees.** 1964 FAO/IUFRO Symp. Doc. on Internationally Dangerous Forest Diseases and Insects: IV-V (i, ii, iii) 1-43.
The host range, symptoms, distribution, and transmission of the known virus and viruslike disorders of forest trees as reported in the world literature.

Shigo, Alex L.
1966. **Defects in birch associated with injuries made by *Xyloterinus politus* Say.** U. S. Forest Serv. Res. Note NE-49, 7 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
A brief pictorial description of the internal defects in paper birch and yellow birch that are associated with external signs of infestation by the ambrosia beetle *Xyloterinus politus*.

Shigo, Alex L.
1966. **Decay and discoloration following logging wounds on northern hardwoods.** U. S. Forest Serv. Res. Paper NE-47, 43 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
Relationships between logging wounds and internal defects. Statistical analysis of the data indicates that most of the measurable external signs were not dependable as indicators of the extent of internal defect in the tree. Time was the most dependable factor affecting the extent of defect associated with logging wounds.

Shigo, Alex L.
1966. **Organism interactions in decay and discoloration in beech, birch, and maple.** *In* Holz and Organismen vol. 1, 309-324, illus. Duncker & Humblot, Berlin.
Results from physiological and ecological studies indicated that bacteria, non-hymenomycetes, and hymenomycetes were all important in the processes that lead to discoloration and decay in living beech, birch, and maple trees.

Shigo, Alex L.
1965. **Decays and discolorations in northern hardwoods in the north-**

eastern United States: A consideration of micro-organisms and external signs. IUFRO Section 41, vol. 3: 1-15, illus. Melbourne, Australia.

Describes the principal infection courts for organisms that cause discolorations and decays in northern hardwoods. The internal defects associated with these external indicators are discussed.

Shigo, Alex L., Edward M. Sharon, and Robert W. Brandt.

1966. **Discoloration and decay following inoculations of northern hardwoods with hymenomycetes.** (Abstr.) Phytopathol. 56: 900-901.

Results from inoculation studies give added importance to the roles that pioneering organisms have in the success or failure of later invading hymenomycetes in living northern hardwoods.

Smith, H. Clay.

1966. **Epicormic branching on eight species of Appalachian hardwoods.** U. S. Forest Serv. Res. Note NE-53, 4 pp. NE. Forest Exp. Sta., Upper Darby, Pa.

Results of a study evaluating bole sprouting of the more important hardwood species found on the Fernow Experimental Forest in West Virginia.

Sopper, W. E., I. C. Reigner, and R. R. Johnson.

1966. **Effect of phenoxy herbicides on riparian vegetation and water quality.** Weeds, Trees and Turf 5 (1): 8-10, illus.

In a cooperative study, 2,4-D and 2,4,5-T were sprayed on riparian vegetation on two small forested watersheds to determine if the water supplies would be contaminated by this treatment. Odor-testing of water samples indicated that contamination of streamflow occurred only immediately after spraying and after the first storm. No contamination was found in samples taken 1 mile downstream. Properly applied, it appears that phenoxy herbicides can be used to control riparian vegetation without constituting a water pollution hazard.

Striffler, W. David

1965. **Selection of experimental watersheds and methods in disturbed forest areas.** Int. Assn. Sci. Hydrol. Symp. 66: 464-473, illus. Budapest.

Mountain watersheds in many areas are undergoing severe mechanical disturbances such as intensive road construction and surface mining. Research methods for evaluating watersheds have generally followed three basic approaches: runoff plots, paired watersheds, and single watershed methods. A relatively new approach, the multiple watershed method, offers many advantages in evaluating streamflow, sediment, and geochemistry. These parameters are related to such variables as watershed area and area of disturbance in a large number of non-uniform watersheds.

Striffler, W. David, and Robert F. May.

1966. **Forest restoration of strip-mined areas.** Soc. Amer. Foresters Proc. 1965: 105-108, illus.

Reviews the problems created by strip-mining for coal in the Appalachian Province. Research efforts have demonstrated that most spoil banks can in time be restored to a productive state, but there are still many gaps in our knowledge and much research is needed before restoration can be accomplished for all areas.

Trimble, George R. Jr., and Lester McClung.
1966. **Clearcutting.** W. Va. Conserv. 30 (7): 16-18.
Explains how the use of even-aged management and clearcutting have proven to be a valuable means of increasing timber yields without sacrifice of water, wildlife, or other forest resources.

Trimble, George R. Jr., and Lester McClung.
1966. **Clearcutting profitable.** W. Va. Conserv. 30 (9): 2-4, illus.
Second part of the two-part article above.

Trimble, G. R. Jr., and Robert S. Manthy.
1966. **Implication of even-aged management on timber.** Soc. Amer. Foresters Allegheny Sect. Proc. 1965: 62-75.
The advantages of even-aged and uneven-aged timber management are discussed, and a hypothetical case study is developed to compare the monetary returns from the two management systems in cove hardwoods. Even-aged management is shown to be the more profitable of the two systems, but management objectives of certain kinds of landowners may favor selection cutting.

Trimble, G. R. Jr., and E. H. Tryon.
1966. **Crown encroachment into openings cut in Appalachian hardwood stands.** J. Forestry 64: 104-108, illus.
The crowns of trees bordering small openings made for reproduction in hardwood stands gradually encroach upon and reduce the effective size of the opening. A regression equation relates the amount of crown expansion into openings to tree d.b.h. and the number of years since cutting. Red oak crowns in the stands studied extended farther and grew faster laterally than yellow-poplar crowns, but the rate of encroachment was surprisingly low for both species.

Trimble, George R. Jr., and George W. Wendel.
1966. **A cost figure for chemical release in Appalachian hardwoods.** N. Logger 14 (7): 24, 42 illus.
A study on the Fernow Experimental Forest in West Virginia provides an estimate of the cost of killing the small stems remaining on a cutover area after a seed tree cutting. Approximately 264 stems/acre between 1.0 and 5.0 inches d.b.h. were treated with a basal spray of 2,4,5-T in oil. Labor costs averaged $2.61 per acre, materials averaged $2.65 per acre, for a total cost of $5.27 per acre or about 2 cents per stem.

Wahlgren, Harold E., Arthur C. Hart, and Robert R. Maeglin.
1966. **Estimating tree specific gravity of Maine conifers.** U. S. Forest

Serv. Res. Paper FPL-61. Forest Prod. Lab., Madison, Wis. 22 pp., illus.

To use the specific gravity of a breast-height increment core in estimating the specific gravity of the merchantable portions of a tree, regression equations were developed for eight coniferous species in Maine. The trend in specific gravity with height-in-stem is shown, each species exhibiting a characteristic pattern.

Weigle, Weldon K.

1966. **Erosion from abandoned coal-haul roads.** J. Soil and Water Conserv. 21 (3): 98.

In a survey of abandoned coal-haul roads in eastern Kentucky, it was found that erosion from the road surface amounted to 2.6 and 5 inches of soil respectively for roads built on sandy silt and silt soils. This amounts to 1.7 to 3.3 acre feet of soil per mile of road each year.

Weigle, Weldon K.

1966. **Road erosion and spoil-bank stability.** *In* Pa. State Univ. Coal Mine Spoil Reclamation Symp. Proc. 1965: 82-85.

Coal-haul roads and spoil banks expose large quantities of soil to erosion; and steep spoil banks occasionally slide, causing extensive local damage. There is no known way to completely eliminate erosion, but good engineering and reclamation practices will control slides and minimize erosion until the land can be returned to productive use through revegetation or other measures. The causes, current practices, and practical solutions of these problems are discussed.

Weigle, Weldon K.

1966. **Spoil bank stability in eastern Kentucky.** Mining Congr. J. 52 (4): 67-73, illus.

A study of slides in eastern Kentucky shows that relatively stable spoil banks can be insured by control of fill-bench widths. The steeper the slope, the narrower the fill bench must be. A chart relates the percent of original slope to the width of the fill bench.

Wen, C. Y., and H. P. Simons.

1966. **Utilization of forestry wastes for power generation.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 95-99.

A chemical analysis is given on the potential recovery of usable products from forest wastes. Problems of recovery are discussed giving consideration to the feasibility of modifying some existing equipment using a wet oxidation process for power production and obtaining chemical components as a by-product of the power generation.

Wendel, George W.

1966. **Aerial spraying of low-grade hardwood stands with 2,4,5-T in West Virginia.** U. S. Forest Serv. Res. Note NE-45, 4 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

Aerial spraying appears to be an economical method of controlling hardwoods on poor sites being converted to conifers. A study in West Virginia showed that helicopter spraying of 2,4,5-T kills more than

90 percent of some species such as the oaks; but the hickories and serviceberry were only slightly affected. The overall killing effect was good in the overstory, but poor in the understory.

Whittaker, James C.
1966. **How to increase profits sawing small logs into thick lumber and timbers.** S. Lumberman 213 (2656): 129-130.
Sawmill operators that cut small oaklogs into products greater than 8/4-inch thicknesses can realize greater operating margins than those who produce only 4/4-inch thick materials from such logs. Such increases result from three things: (1) increased volume recovery; (2) decreased sawing time per board foot; and (3) favorable prices for thick products as compared to low-quality 4/4-inch boards.

Whittaker, J. C.
1966. **Commercial outdoor recreation — an important use of Ohio's** lakes and ponds. Ohio Woodlands, Conserv. in Action 6 (2): 3.
Describes the commercial significance of ponds and lakes upon private outdoor recreation in Ohio. Of 146,750 acres of ponds and lakes used for outdoor recreation in Ohio, 10,189 acres (7 per cent) belong to privately operated outdoor recreation businesses. More than one-third of these 10,189 acres are owned by non-water oriented recreation businesses.

Whittaker, James C., and Orris D. McCauley.
1966. **Costs and returns for hardwood lumber production in the Appalachian region of Kentucky and Ohio.** U. S. Forest Serv. Res. Paper NE-55, 10 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
Study of costs and returns at seven circular sawmills revealed how unit costs vary with types of markets for which lumber is produced, volume sawed annually, and amount of processing and seasoning done to lumber produced. Suggests how managers should direct cost-control efforts to increase operating profits.

Williamson, Malcolm J.
1966. **Premature abscissions and white oak acorn crops.** Forest Sci. 12: 19-21, illus.
Most of the potential white oak acorns (more than 96 percent in this study) fall off the tree before they mature, drastically reducing the supply available for wildlife and the reproduction of white oak stands. In this study of white oak flowering and fruiting, more than 80 percent of the premature abscissions occurred during the periods of pollination, ovule development, and fertilization.

Wilson, Robert W. Jr., and Ashbel F. Hough.
1966. **A selected and annotated bibliography of eastern white pine *(Pinus strobus* L.), 1890-1954.** U. S. Forest Serv. Res. Paper NE-44, 166 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
Most of the 944 literature references listed deal directly with the silvics, phptosociology, silviculture, protection, and management of

white pine. In addition, many of the significant publications on taxonomy, morphology, physiology, genetics, wood anatomy, wood technology, logging, manufacturing, end uses and marketing, and resource and economic statistics are included.

Wood, Francis A., and Robert A. Schmidt.
1966. **A spore trap for studying spore release from basidiocarps.** Phytopathol. 56: 50-52.
A spore trap for studying spore liberation from sporophores of bracket fungi was developed and tested. These traps and associated timing device provide a means of sampling several sporophores simultaneously.

Wren, Thomas E.
1966. **Rubber-tired skidders — environmental factors.** N. Logger 14 (11): 18-19, illus.
Environmental factors affecting the performance of wheeled skidders are analyzed by industrial engineering methods.

Wren, Thomas E.
1966. **A system approach to wheel skidder operations in Appalachian terrain.** *In* Proc. Forest Eng. Symp. W. Va. Univ. Tech. Bull. 82: 30-38, illus.
A mathematical approach for estimating harvesting costs for wheeled skidder logging operations in Appalachian terrain.